Samuhik Pahal

सामूहिक पहल

A journal of our collective action

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Computer science education in schools

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This issue of Samuhik Pahal has been guest edited by Pi Jam Foundation, which is a nonprofit organization established in September 2017. It aims to equip children and educators of India with access to affordable technology and enhanced quality of computer science education.

The unfolding story of taking computer science learning to the next level, with all hands on deck

Pi Jam Foundation Team

14-year-old Mushahid Khan is not your regular poster boy for the glossy ed tech ads for “Can your child code?” A student of Mumbai’s Maneklal Municipal Hindi School and a resident of Ghatkopar, he has built a game using opensource software, to raise awareness about child safety for the parents in the neighborhood.

Yashoda, an instructor at Pi lab, set up a computer lab in the kitchen of her small house in Ganga Khed, a village in Parbhani, Maharashtra, taking lessons for 25 students through the pandemic. All she needed was a tiny credit-card-sized Raspberry Pi device that doubles up as a central processing unit, and some training.

We have known for a while the sheer power of computer science (CS) education and the impact CS-related skill sets are going to have on the future of our children. CS education is of course critical in terms of opening employment opportunities. Apart from that, through CS, today’s children can meaningfully contribute to the world in the future through their problem-solving, analytical and design thinking skills. Building competence in computer science also feeds into children’s wide-eyed curiosity. It gives them a sense of comfort and familiarity with the digital landscape, likely to translate into more future opportunities.

NEP 2020 addresses the need to bridge the gap between traditional school learning and the acquisition of practical and future skills. This is a crucial aspect, as the outcomes of school education must lay a strong foundation for children to excel in their future careers and in life, of which CS is emerging as a significant component.

However, a question that begs asking is - have we democratized computer science learning enough? If so, what is the quality of CS learning that we are imparting to students at the bottom of the socio-economic pyramid? How diverse and penetrative is the access to computer science education as it should be taught?

As you will discover in this issue, various non-government organizations along with government agencies (like Government of Goa’s coding and robotics program CARES, or Government of Delhi’s inclusion of future skills-focused courses and curriculum covering AI, machine learning and coding), CSR entities and big-tech (a hat tip to the work being done by companies like Amazon through its Amazon Future Engineer initiative, and CGI) are working dedicatedly with educationists in this direction.

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These varied sets of actors are making and driving policies, framing pedagogies that integrate CS learning in ways that develops specific future skills in children. These include computational thinking, design thinking (identifying problem around to charting out the best solution path), analytical problem solving, creativity and logical reasoning. In other words, the attempt now is to make quality CS learning available to every child, so that no child gets left behind in having a place at the table when an inclusive, solution-centric, imaginative tech-driven future is being shaped. There are challenges, like the demography, reach, infrastructure, advocacy and awareness. However, solutions are in sight too!

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NEP 2020 envisages a shift to a system where, “Children not only learn but more importantly learn how to learn.” It goes on to say that the “pedagogy must evolve to make education more experiential, inquiry-driven, flexible,” an acknowledgment that has given a boost to our approach to computer science learning. If voices from the ground that you'll read in the ‘Insights’ section of this issue of *Samuhik Pahal* are anything to go by, the results are reassuring.

To make education and learning outcomes more effective, educationists are making a case for children to learn coding early, like languages and arithmetic. Programming has been encouraged as a tool to introduce computational thinking, which means to think or look at a problem like a computer scientist. As a researcher points out in this issue, scientists further argue that although computational thinking represents an excellent starting point, the broader conception of ‘computational participation’ better captures the twenty-first-century reality.

As Dr Chintan Vaishnav, Director, Atal Innovation Mission (AIM) shares in an interview in the issue, “When you look at school labs, there have been two waves before the makers' lab wave, the science labs wave and the computer labs wave, which are very different from each other. The makers' lab was possibly the first time that both minds and hands were involved. In science labs, they prove what is known, in computer labs, they digitize what is not digital, and in makers' labs, they create thoughts!”

Cases in point - using technology to grow plants with minimal human intervention; building local weather systems; writing codes to automate irrigation pumps for farmers, and; building motion sensors to read potholes based on pothole data repositories - low-cost, scalable computer science education is helping children relate computational learning with their social realities and problems, apart from implementing scientific and mathematical concepts they learn in their regular classes.

We must create a generation of kids who are computational thinkers, problem solvers, design thinkers, innovators and analysts, and not merely good at a particular skill subset, namely coding in this case.

Various initiatives, including Nipun Bharat, have offered to fill the lacunae in the Indian education system, influencing the prospects and design of NEP 2020. The COVID-19 pandemic has essentially thrust technology into the hands of everyone. While the educational technology sector has been at the center of this transition, distinct gap remains between access, agency and utilization of the tools. More access, while needed, does not alone ensure cultivation of agency for learning and problem solving or indeed improvement in learning outcomes.

There is a need to delve into the essence of education itself, to understand the quality of outcome in the above context. Education, in its truest sense, has two dimensions. The first pertains to skills and the job economy, where education aligns with future career prospects. The second dimension delves into the elevation of the human soul, the cultivation of agency, and empowerment.

Can the children think on their own? Can children use digital tools to solve the problems they observe in their environment? In this modern age, technology has now been seamlessly integrated into our daily existence, influencing the way we interact with the world. But not every learner has been able to exploit this integration to her best potential, just yet.

This is where what we do in the field of CS education as part of the educational overhaul becomes so important. It's not just about technology proficiency. It is about cultivating agency in the digital era. The creative dimension becomes paramount for children's development, as creativity takes various forms and is instrumental in participatory problem-solving and critical thinking. Computer Science doesn't merely provide comfort with technology. It serves as a catalyst for nurturing creativity, honing logical problem-solving skills, and facilitating an understanding of the world. Against this backdrop, the role of nonprofit agencies dedicated to improving access and quality of digital education in India is critical to ensure that children are equipped with 21st century digital skills. Our mission must be to democratize computer science learning across the entire country, along with building agency, nurturing problem-solving and creative skills in learners.

The essence of agency varies from a school in Kupwara (in Jammu and Kashmir) to a crowded school in BMC (Brihanmumbai Municipal Corporation, or Municipal Corporation of Greater Mumbai). Similarly, the stories of teachers adopting computer science learning modules, and using low-cost tech to do the same as part of their teaching armors, is inspiring. It showcases the shift from mere digital access to its effective utilization. It is about acknowledging that having access to technology is not enough. It is about integrating it into students' learning experiences. This is where nonprofit organizations must step in, creating a bridge between technology, creativity and education, ensuring that the digital realm becomes a tool for empowering young minds, across the socio-economic spectrum.

Pi Jam Foundation

कम्प्यूटेशनल चिन्तन

एक सम-सामयिक नया विचार

आर रामानुजम

सम-सामयिक नया विचार

1980 के दशक में कम्प्यूटर विज्ञान में समस्याओं पर काम करने वाले किसी व्यक्ति के तौर पर मुझसे अक्सर यह पूछा जाता था : *आप किन भाषाओं में काम करते हैं?* मैं आमतौर पर इस प्रश्न को जान-बूझकर ग़लत समझता और उत्तर देता – *ज़्यादातर अँग्रेज़ी में, कभी-कभी तमिल में भी।* उन दिनों कम्प्यूटर के साथ काम करने का मतलब था फोरट्रान या कोबोल या सी भाषा में कम्प्यूटर के प्रोग्राम लिखना और प्रश्नकर्ता मुझसे यही पूछ रहे होते थे। मेरा जवाब प्रोग्रामिंग भाषा के अप्रासंगिक होने और अन्तर्निहित अवधारणाओं के अधिक महत्त्वपूर्ण होने के बारे में होता था। वास्तव में, इस प्रश्न का एक अधिक सटीक लेकिन पूर्णत: अस्पष्ट उत्तर होगा *फर्स्ट ऑर्डर लॉजिक* और कुछ हद तक, बीजगणित। यह कम्प्यूटेशन के बारे में अमूर्त तर्क (abstract reasoning) के लिए भाषाएँ हैं।

यह सब इस बात को बताने के लिए है कि कम्प्यूटिंग और कम्प्यूटर विज्ञान के बारे में लोगों की आम-धारणा उस *सोच* को प्रतिबिम्बित नहीं कर सकती है जो इन अनुशासनात्मक क्षेत्रों (disciplinary domain) का मूल है। (यह काफ़ी स्वाभाविक है, इलेक्ट्रिकल इंजीनियरों या पुरातत्वविदों द्वारा उपयोग की जाने वाली विधियों की आम धारणा भी सटीक होने की सम्भावना नहीं है।) ज़रूरी नहीं है कि आधुनिक जीवन पर कम्प्यूटरों के बढ़ते प्रभाव के कारण यह उम्मीद की जाए कि लोगों को इस तरह की समझ भी हो : जैसे लोग बार-बार डॉक्टर से परामर्श करते हैं, पर उनसे चिकित्सीय निदान या पर्चे को समझने की उम्मीद नहीं की जा सकती।

जब स्कूली शिक्षा में इस तरह के “अनुशासनात्मक विचार” की वकालत की जाती है, तब इस तरह के विचारों की जाँच करना महत्त्वपूर्ण हो जाता है और जब बात स्कूली शिक्षा की हो तो आम धारणा और जुड़ाव महत्त्वपूर्ण होता है। पिछले एक दशक में कई देशों में इस बात की माँग बढ़ी है कि कम्प्यूटेशनल चिन्तन (Computational thinking – CT) को स्कूली पाठ्यचर्या का हिस्सा बनाया जाए। भारत में, राष्ट्रीय शिक्षा नीति, 2020 (एनईपी) ने न केवल **सीटी** (इस लेख में आगे हम इसे **सीटी** ही कहेंगे) को महत्त्व दिया है, बल्कि इसे *गणितीय चिन्तन* (Mathmatical thinking) के साथ भी जोड़ा है। हालाँकि इससे देश में काफ़ी चर्चा का माहौल बना है, फिर भी यह बिलकुल अस्पष्ट है कि क्या इस बात को लेकर शिक्षकों और शिक्षक-समुदाय के बीच एक स्पष्ट धारणा है कि **सीटी** क्या है, इसे गणितीय चिन्तन के साथ क्यों जोड़ा जा रहा है और क्या स्कूलों में **सीटी** को बढ़ावा देना ज़रूरी है या लाभप्रद है ।

इस सन्दर्भ में यह लेख निम्नलिखित प्रश्नों को उठाने और उन पर चर्चा करने का प्रयास करता है :

- क्या आधुनिक जीवन में कम्प्यूटर की सर्वव्यापकता (अ) स्कूल में कम्प्यूटिंग सीखने और (बी) स्कूल में **सीटी** सीखने को बढ़ावा देने के लिए पर्याप्त कारण है?
- कक्षा में डिजिटल प्रौद्योगिकी की भूमिका के साथ **सीटी** का क्या लेना-देना है? डिजिटल स्पेस में देश में बड़े पैमाने पर मौजूद असमानता को देखते हुए **सीटी** और डिजिटल प्रौद्योगिकी को बढ़ावा देना क्या सामाजिक विभाजन को और गहरा नहीं करेगा?
- **सीटी** का कम्प्यूटर प्रोग्रामिंग सीखने से क्या लेना-देना है और बच्चों को कोडिंग सीखना कब शुरू करना चाहिए?
- **सीटी** का स्कूली गणित से क्या लेना-देना है? पहले से ही ठसाठस भरी हुई गणित पाठ्यचर्या के साथ अतिरिक्त विषयों को जोड़कर क्या हम विद्यार्थियों और शिक्षकों पर बोझ बढ़ा रहे हैं?
- क्या भारतीय शिक्षा-प्रणाली स्कूलों में **सीटी** को अपनाने के लिए तैयार है?

वास्तव में, प्रश्नों की यह सूची पूरी नहीं है और आने वाले वर्षों में एनईपी के क्रियान्यवन के दौरान सभी स्तरों पर और अधिक प्रश्न उत्पन्न होंगे। हालाँकि, एक राष्ट्रीय नीति को इन मूलभूत प्रश्नों के उत्तर देने और विशेष रूप से शिक्षण समुदाय को स्पष्ट निर्देश प्रदान करने की आवश्यकता है।

एनईपी में सीटी

भारत में एक विषय के रूप में कम्प्यूटर विज्ञान मुख्यत: विश्वविद्यालयों में पढ़ाया जाता है और उच्च माध्यमिक स्तर पर इसके लिए कुछ तैयारी की जाती है। स्कूल के प्रारम्भिक 10 वर्षों में तथाकथित *कम्प्यूटर कक्षाएँ* मुख्यत: कम्प्यूटर, प्लेटफार्मों और इंटरनेट के उपयोग पर आधारित रही हैं। यह भी मुख्यत: शहरी निजी स्कूलों में है; सरकारी स्कूल-प्रणाली में बड़े पैमाने पर सामान्यत: केवल माध्यमिक या उच्चतर माध्यमिक विद्यालय स्तर पर कम्प्यूटर के उपयोग से परिचय कराया जाता है।

एनईपी भी स्कूली वर्षों में कम्प्यूटेशनल चिन्तन और कोडिंग की वकालत करती है। एनईपी से यह प्रासंगिक हिस्सा यहाँ प्रस्तुत करने लायक है :

> 4.25 यह माना जाता है कि गणित और गणितीय चिन्तन भारत के भविष्य और कई आगामी क्षेत्रों और व्यवसायों में

> भारत की नेतृत्वकारी भूमिका के लिए बहुत महत्त्वपूर्ण होगा। इन उभरते हुए क्षेत्रों में आर्टिफिशियल इंटेलिजेंस, मशीन लर्निंग और डेटा साइंस शामिल हैं। इस प्रकार गणित और कम्प्यूटेशनल चिन्तन को विभिन्न प्रकार के अभिनव तरीक़ों के माध्यम से फ़ाउंडेशनल स्तर से शुरू करके स्कूल की पूरी अवधि के दौरान विभिन्न तरीक़ों, जिनमें पहेलियाँ और गेम का नियमित उपयोग शामिल है (और जो गणितीय चिन्तन को अधिक आनन्ददायी और आर्कषक बनाते हैं), के माध्यम से सिखाने पर ज़ोर दिया जाएगा। मिडिल स्कूल स्तर पर कोडिंग सम्बन्धी गतिविधियाँ शुरू की जाएँगी।

गणितीय चिन्तन और कम्प्यूटेशनल चिन्तन का जुड़ाव महत्त्वपूर्ण है, क्योंकि यह "कम्प्यूटर कक्षाओं" के वर्तमान मॉडल को पूरी तरह से हटाने और कम्प्यूटिंग के आधारभूत विज्ञान को पढ़ाने के लिए आगे बढ़ने का सुझाव देता है। इसमें चिन्तन पर ज़ोर दिया जा रहा है। इसका गणित-शिक्षा के लिए भी महत्त्वपूर्ण निहितार्थ है क्योंकि इसमें "संक्रियाओं", सूत्रों और प्रक्रियाओं (समीकरणों को हल करने के लिए, आदि) को सीखने की बजाय चिन्तन के तरीक़े को सीखने पर ध्यान केन्द्रित किया जा रहा है।

दूसरी ओर, इस गद्यांश के अनुसार ऐसा किए जाने का कारण "आगामी क्षेत्रों और व्यवसायों जैसे आर्टिफिशियल इंटेलिजेंस, मशीन लर्निंग और डेटा साइंस आदि के लिए गणित और कम्प्यूटेशनल चिन्तन के महत्त्व से उपजा है।" इसके अलावा, माध्यमिक स्तर से आगे के लिए कोडिंग की वकालत की गई है। इस स्थिति में किसी को यह सोचने के लिए माफ़ किया जा सकता है कि **सीटी**, जिसे वर्तमान में कम्प्यूटर विज्ञान में महत्त्वपूर्ण माना जाता है, की वकालत केवल फैशन को बढ़ावा देने के लिए है और इसका सम्बन्ध कोडिंग के साथ है। (वास्तव में, कुछ लोगों ने पहले से ही हाई स्कूल में आर्टिफिशियल इंटेलिजेंस और डेटा साइंस के शिक्षण की वकालत करना शुरू कर दी है!)

"भारत की नेतृत्वकारी भूमिका" का सन्दर्भ और भी सन्देह पैदा करता है : स्कूली पाठ्यचर्याएँ स्कूली शिक्षा के उद्देश्यों द्वारा तय की जानी चाहिए और बच्चों पर राष्ट्रवादी प्राथमिकताओं की ज़िम्मेदारी का बोझ नहीं डालना चाहिए। फिर से, **सीटी** का प्रचार एक शैक्षिक उद्देश्य के रूप में आवश्यक होने के बजाय सहायक प्रतीत होता है।

एनईपी दस्तावेज़ में "कम्प्यूटेशनल चिन्तन" वाक्यांश का यह एकमात्र उल्लेख है। दूसरी ओर, एनईपी कक्षाओं में डिजिटल प्रौद्योगिकी के उपयोग की पुरज़ोर वकालत करता है। इसके लिए एनईपी में एक पूरा खण्ड समर्पित किया गया है।

इस बीच महामारी के कारण देश को स्कूली शिक्षा में भारी व्यवधान का सामना करना पड़ा और इस दौरान ऑनलाइन शिक्षा (केवल अभिजात वर्ग के लिए सुलभ) ने शैक्षिक प्रौद्योगिकी को प्रमुखता में ला दिया। इसने और भ्रम की स्थिति पैदा कर दी है और कक्षा में डिजिटल प्रौद्योगिकी की भूमिका को **सीटी** और प्रोग्रामिंग सिखाने के साथ मिला दिया है।

इस सबने शिक्षकों के एक बड़े हिस्से को यह विश्वास करने के लिए प्रेरित किया है कि स्कूलों में **सीटी** की शुरुआत का अर्थ है कक्षाओं में डिजिटल उपकरणों का उपयोग करना और शायद नए विषयों के रूप में "डेटा साइंस" और "आर्टिफिशियल इंटेलिजेंस" के साथ कम उम्र से ही प्रोग्रामिंग को पढ़ाना।

एक वास्तविक *ख़तरा* यह है कि सम्भवत: एनईपी के माध्यम से **सीटी** का प्रचार इसके क्रियान्वयन के दौरान इस रूप में समाप्त हो : डिजिटल उपकरणों को बढ़ावा देना और कम उम्र से ही कोडिंग शिक्षण पर ज़ोर देना। यदि ऐसा हुआ तो यह वास्तव में एक ख़ेदपूर्ण परिणाम होगा।

सीटी क्या है?

सीमोर पेपर्ट [सन्दर्भ 4], एक अमेरिकी कम्प्यूटर वैज्ञानिक जिन्होंने सबसे पहले बच्चों के लिए कम्प्यूटर प्रोग्रामिंग गतिविधियाँ विकसित कीं, ने 1980 में 'कम्प्यूटेशनल थिंकिंग' शब्द गढ़ा। यह वाक्यांश "कम्प्यूटेशनल थिंकिंग" माइंडस्टॉर्म्स (पृष्ठ संख्या 182) में दिखाई देता है, लेकिन बिना विस्तार के। हम 1996 के उनके पेपर [सन्दर्भ 5] "एन एक्सप्लोरेशन इन दि स्पेस ऑफ़ मैथमेटिक्स एजुकेशन" में इस विचार का एक विस्तृत विवरण पाते हैं। इसमें वह *ऑब्जेक्ट बिफोर ऑपरेशन* (object before operation) का सिद्धान्त प्रदान करते हैं : गणितीय विचारों का "चीज़नुमा निरूपण" करना (प्रोग्रामों की सूक्ष्म दुनिया का उपयोग करना) उनके बारे में सोचने में मदद करता है।

जेनेट विंग, एक अन्य अमेरिकी कम्प्यूटर वैज्ञानिक, ने 2006 में इस शब्द को लोकप्रिय बनाया ([सन्दर्भ 6], [सन्दर्भ 7])। वह इसे एक "दृष्टिकोण और कौशल सेट" का नाम देती हैं जिसे हर कोई सीख सकता है और उपयोग कर सकता है। सरल शब्दों में कहें तो सीटी एक ऐसी प्रक्रिया है जो हमें एक जटिल समस्या को लेने, उसे समझने और इस तरह के सम्भावित समाधानों को विकसित करने में सक्षम बनाती है कि कम्प्यूटर या मानव, या दोनों यह समझ सकें कि उस समाधान को कैसे अमल में लाया जाए। यदि "गणितीय चिन्तन" एक गणितज्ञ की तरह सोचना है, तो विंग के लिए, "कम्प्यूटेशनल चिन्तन" एक कम्प्यूटर वैज्ञानिक की तरह सोचना है।

यहाँ जो महत्त्वपूर्ण है, वह है अन्तिम भाग : समाधानों को इस तरह से क्यों विकसित किया जाना चाहिए कि एक कम्प्यूटर उन्हें अमल में ला सके? यहाँ कम्प्यूटर से हमारा क्या मतलब है? कौन-सा कम्प्यूटर? हम उस कम्प्यूटर को कौन-सी क्षमताओं से लैस मान रहे हैं? दूसरे तरीक़े से पूछें तो, यह मानव द्वारा समाधान को अमल में लाने से कैसे अलग है?

ध्यान दिया जाना चाहिए कि यहाँ हमारा आशय विशिष्ट क्षमताओं से लैस किसी विशिष्ट कम्प्यूटर से नहीं है, बल्कि एक आदर्श कम्प्यूटर से है। यांत्रिक संगणना यानी यांत्रिक कम्प्यूटेशन (mechanical computation) का महत्त्वपूर्ण गुणधर्म यह है कि यह पुनरावृत्ति से ऊबता नहीं है या ग़लतियाँ करना नहीं शुरू कर

देता है। एक कैल्कुलेटर के लिए 3 अंकों वाली पाँच संख्याओं को जोड़ने या 500 संख्याओं, जिसमें से कुछ करोड़ों और हज़ारों में हो सकती हैं, को जोड़ने में कोई अन्तर नहीं है।

यहाँ विचार करने योग्य दो मुख्य बातें हैं : डेटा का आकार और एल्गोरिदम की पुनरावृत्ति। कम्प्यूटेशन का मूलभूत गुण *स्केलिंग* (scaling) है। एक बार जब हम इस तरह की प्रक्रियाओं को तैयार कर लेते हैं, जिन्हें पर्याप्त रूप से सरल चरणों में तोड़ा जाता है, तो इन्हें ज़रूरत अनुसार बढ़ाया (scale up) जा सकता है।

विंग के अनुसार, **सीटी** की विशेषताएँ हैं : *अपघटन (decomposition)*, *पैटर्न की पहचान (pattern recognition)* *अमूर्तीकरण (abstraction)* और *एल्गोरिदम (algorithm)*।

- अपघटन हमें जटिल कार्यों को उपकार्यों में, फिर प्रत्येक उपकार्य को उप-उपकार्यों में तोड़ने आदि का मौक़ा देता है जब तक कि प्रत्येक कार्य स्पष्ट रूप से करने के लिए पर्याप्त सरल न हो जाए।
- ऐसा करते समय हम अक्सर पाते हैं कि कुछ कार्य मामूली अन्तर के साथ बार-बार सामने आते हैं, तब हम उन्हें एक ही कार्य के उदाहरण के रूप में मानते हैं— शायद परिवर्तन को समझने के एक मानक के साथ। यह पैटर्न पहचानने और अमूर्तीकरण की प्रक्रियाएँ हैं।
- एल्गोरिदम चरणबद्ध प्रक्रियाएँ हैं जो 'सर्वोत्तम सम्भव' तरीक़े से उपकार्यों को अनुक्रमित करती हैं। **सीटी** में न केवल समस्या को हल करने के लिए ऐसी कार्यप्रणाली शामिल है, बल्कि समाधानों की तुलना करने और उनका मूल्यांकन करने के तरीक़े भी शामिल हैं।

रोज़मर्रा के एक उदाहरण के रूप में, 4 व्यक्तियों के लिए रात का खाना तैयार करने पर विचार करें। इसके लिए पर्याप्त रूप से योजना बनाने की ज़रूरत है। जब तक हम एक मेन्यू तय नहीं कर लेते हैं, तब तक हम सामग्री नहीं ख़रीद सकते। हालाँकि, यह हो सकता है कि कुछ सामग्री उपलब्ध नहीं हो और इसलिए हमें मेन्यू को बदलने की आवश्यकता हो। एक बार जब हमारे पास सामग्री और रसोई के आवश्यक उपकरण हो जाएँ और तब अगर हमारे पास खाना पकाने वाले दो व्यक्ति हैं, तो हम तय करते हैं कि एक-दूसरे का इन्तज़ार किए बिना कौन-से काम किस क्रम में किए जाने हैं। कुछ कार्यों को निश्चित रूप से दूसरों की तुलना में पहले करना होगा।

खाना पकाने की विधि स्पष्ट होनी चाहिए और इसका ध्यानपूर्वक पालन किया जाना चाहिए। शुरुआत से ही सुरक्षा का ध्यान रखा जाना चाहिए और सुरक्षा और स्वाद दोनों के लिए कुछ "रनटाइम चेक" किए जाने चाहिए। यदि इस सबके अन्त में, आपको लगता है कि आपके पास 4 व्यक्तियों का खाना बनाने के लिए एक विश्वसनीय प्रक्रिया है, तो विचार करें कि 20 व्यक्तियों के खाने के लिए और 100 मेहमानों के लिए (एक शादी में) इसे कैसे बढ़ाया जा सकता है। इसके अलावा, एक ही मेन्यू के लिए या विभिन्न मेन्यू के लिए किसी अन्य व्यक्ति की विधियों के साथ इस प्रक्रिया की तुलना करें। इन सभी में शामिल प्रक्रियाएँ **सीटी** को दर्शाती हैं।

यह उदाहरण दर्शाता है कि कम्प्यूटेशनल चिन्तन रोज़मर्रा के सन्दर्भों में प्रासंगिक है। यहाँ "कम्प्यूटर" की धारणा अमूर्त है और किसी भी विशेष मशीन की ओर इशारा नहीं करती है। इसी तरह, खाना बनाने की विधि किसी प्रोग्रामिंग भाषा में लिखा गया प्रोग्राम नहीं है, लेकिन यह सम्प्रेषण के उद्देश्य को पूरा करता है। वास्तव में **सीटी** के इस दृष्टिकोण को इलेक्ट्रॉनिक उपकरणों की आवश्यकता बिलकुल भी नहीं है और हम *कम्प्यूटर विज्ञान "अनप्लग करने की"* की बात कर सकते हैं! [सन्दर्भ 1]

इस प्रकार कम्प्यूटेशनल चिन्तन का केन्द्रीय तत्व **प्रक्रियाओं के बारे में तर्क करना** है। कई एल्गोरिदम और प्रक्रियाओं को जानना या विशिष्ट कोड लिखना, प्रक्रियाओं और एल्गोरिदम को डिज़ाइन करने में सक्षम होने, उनके कार्य करने के तरीक़ों के बारे में तर्क करने, उनके प्रदर्शन का आकलन करने, वैकल्पिक तरीक़ों की पड़ताल करने और उनकी तुलना करने में सक्षम होने से कम महत्त्वपूर्ण है। डेटा संरचनाओं (data structure) की परिभाषाओं को जानना यह समझने से कम महत्त्वपूर्ण है कि डेटा को कई तरीक़ों से कैसे व्यवस्थित कर सकते हैं, यह उन प्रक्रियाओं को कैसे प्रभावित करता है जो इनका उपयोग करती हैं और कौन-सा व्यवस्थापन किस आवश्यकता के अनुरूप है।

इस दृष्टिकोण से, कम्प्यूटेशन का फोकस कम्प्यूटिंग उपकरणों के बजाय ऐसी सोच को विकसित करना माना जाता है जिसमें कम्प्यूटेशन शैक्षिक लक्ष्य का *आधार* बन जाता है। इस तरह के चिन्तन से विद्यार्थियों को डेटा को व्यवस्थित करने, स्केलिंग, प्रक्रियाओं का आकलन करने व उनकी तुलना करने, पुनरावृत्ति और मॉड्यूलर अमूर्तीकरण को समझने में मदद मिलती है, फिर चाहे समाधान कम्प्यूटर द्वारा माँगे जाएँ या कम्प्यूटिंग प्लेटफार्मों पर कार्यान्वित किए जाएँ। इसका एक उदाहरण होगा पूर्णांकों के गुणन या भाग के लिए कई प्रक्रियाओं का ज्ञान होना और यह समझना कि किस समय किस विधि का उपयोग करना सबसे बेहतर रहेगा।

जब हम एक बच्चे को 53 + 28 + 47 जोड़ने के लिए कहते हैं, तो बाएँ से दाएँ (या ऊपर से नीचे, संख्याओं को ऊर्ध्वाधर रूप से रखकर जोड़ना, जैसा कि बच्चे अक्सर करते हैं) जोड़ना बिलकुल ठीक है। लेकिन यह कम्प्यूटेशनल सहज ज्ञान है जो हमें (53 + 47) को पहले जोड़कर फिर इसमें 28 को जोड़ने का सुझाव देता है। इससे हमें न केवल जल्दी समाधान मिलता है, बल्कि यह अधिक सुविधाजनक है क्योंकि हम दशमलव प्रणाली के साथ काम करने के अभ्यस्त हैं और 10 के गुणज हमारे लिए महत्त्वपूर्ण हैं। बतौर "कम्प्यूटर" यह पुनर्व्यवस्थापन (reformulation) हमारे लिए आसान है। योग का क्रमचयी गुणधर्म हमें ऐसा करने की अनुमति देता है और यह गणितीय समझ ही इस तरह के कम्प्यूटेशनल चिन्तन का आधार है।

इस बात को विस्तार से बताने के जोखिम पर, इस समीकरण को हल करने पर विचार करें : $2(x+1) + 3(x+1) = 10$। एक बार फिर बतौर मानक तकनीक कोष्ठक खोलकर विस्तार करने, x वाले समान पदों को बाईं ओर एवं अन्य पदों को दाईं ओर रखने, और फिर विभाजित करने में कोई नुकसान नहीं है। हालाँकि, बीजगणितीय कम्प्यूटेशन हमें बताता है कि समीकरण को $5(x+1) = 10$ के रूप में फिर से लिखा जा सकता है, जो कि हमें तुरन्त समाधान देता है। एक बार फिर, यह समीकरण को जल्दी हल करने के बारे में नहीं है, बल्कि सुविधा के बारे में है : यहाँ हम कम्प्यूटिंग कर रहे हैं; इसलिए हम कम्प्यूटिंग के विभिन्न तरीक़ों पर विचार करते हैं और चुनते हैं कि कौन-सा तरीक़ा हमारे लिए सबसे बेहतर है।

इस तरह के प्रश्न पर विचार करें : $2x^2$-50 या x^2+100 में से किसका मान तेज़ी-से बढ़ता है? यह जानकारी कि जैसे-जैसे x का मान बढ़ता है एक अचर राशि को जोड़ने या घटाने से कोई फ़र्क़ नहीं पड़ता है, मूलत: कम्प्यूटेशनल सहज ज्ञान है। साथ ही यह तथ्य भी कि फलन $2x^2$ का मान हमेशा x^2 से ज़्यादा होता है। इस तरह के सहज ज्ञान में अन्तर्निहित गणितीय औचित्य को अवकलजों (derivatives) का कम्प्यूटेशन करके और उनकी तुलना करके प्रदान किया जा सकता है।

यहाँ जिस बात पर ज़ोर दिया जा रहा है, वह यह है कि कम्प्यूटेशनल चिन्तन में न केवल प्रक्रियाओं को ईजाद करना और डेटा को उचित रूप से (पुन:)व्यवस्थित करना शामिल है, बल्कि कुछ मापदण्डों के अनुसार स्पष्ट रूप से व्यक्त वैकल्पिक प्रक्रियाओं पर विचार करना और उनमें से “सर्वश्रेष्ठ” को चुनना भी शामिल है। तभी **प्रक्रियाओं के बारे में तर्क** केन्द्रीय महत्त्व ग्रहण करता है।

जबकि पूर्वगामी को **सीटी** के मूल अर्थ के रूप में व्यक्त किया जा सकता है, फिर भी कम्प्यूटर के उपयोग से सम्बन्धित इसके सतही अर्थ की भी प्रासंगिकता है। **सीटी** शिक्षा के यह उद्देश्य कम्प्यूटिंग प्लेटफार्मों, उपकरणों और यंत्रों के उपयोग से सम्बन्धित हैं। यह उद्देश्य विद्यार्थियों को न केवल इनके उपयोग में महारत हासिल करने में मदद करते हैं बल्कि उनमें ऐसे शैक्षिक सन्दर्भों की पहचान करने और उपयोग करने के लिए विशिष्ट ढंग से सोचने की प्रवृत्ति उत्पन्न करते हैं जिनमें कम्प्यूटेशन का उपयोग मदद कर सकता है और तदनुसार कम्प्यूटेशन को इस्तेमाल कर सकता है। इस बात का एक उदाहरण किसी सम्भावित प्रस्ताव (जैसे जन्मदिन वाले सवाल - The birthday problem - The birthday problem प्रायिकता का एक मशहूर पज़ल है। - में) की जाँच करने के लिए कुछ बंटन (distribution) के अनुसार डेटा उत्पन्न करना होगा या न्यूटन के नियमों के अनुसार एक गेंद के प्रक्षेपवक्र (trajectory) की प्लॉटिंग करना होगा। मुख्यत: “समय की बाध्यता” हमें इन उद्देश्यों की ओर ले जाती है : चूँकि ऐसे उपकरण प्रचलित हैं और उपयोग करने में आसान हैं। शिक्षकों को इनके “सही” व सुरक्षित उपयोग और शैक्षिक प्रथाओं को समृद्ध करने के ऐसे अवसरों के उपयोग को ख़ुद-ब-ख़ुद शामिल करना चाहिए। यदि आपको लगता है कि हम शिक्षण में ऐसे डिजिटल उपकरणों के उपयोग पर ज़ोर कम दे रहे हैं, तो ऐसा नहीं है कि हम उन्हें **सीटी** के लिए कम महत्त्वपूर्ण या अप्रासंगिक मानते हैं। **सीटी** के पूरी तरह से डिजिटल उपकरणों के उपयोग तक सीमित रह जाने (जो अभी केवल काल्पनिक नहीं लगता है) के ख़तरे का विरोध करने के लिए हमने प्रक्रियाओं के बारे में तर्क करने पर ज़ोर दिया है, जो कि **सीटी** का मूल अर्थ है।

पाठ्यचर्या घटक

स्कूली शिक्षा के लिए **सीटी** की यह समझ क्या मायने रखती है? स्कूल में **सीटी** पढ़ाने में निम्नलिखित घटक शामिल होंगे। यह न केवल अपने आप में **सीटी** शिक्षा से सम्बन्धित हैं, बल्कि **सीटी** द्वारा प्रदान किए गए शैक्षिक अवसरों को भी बढ़ाते हैं। (यह मानना होगा कि यह पूरी तरह से स्वतंत्र घटक नहीं हैं और इनमें आपस में कुछ ओवरलैप हैं।)

i. **स्केलिंग :** प्रासंगिक मापदण्डों की गिनती व व्यवस्थित सूची और यह जाँचना कि सभी को गिना गया है योज्यात्मक तर्क (additive reasoning) से गुणनात्मक तर्क (multiplicative reasoning) की ओर बढ़ने के लिए आवश्यक है। यह फलन परिवर्तन (functional variation) और गणना के लिए सममितियों के उपयोग का मार्ग भी प्रशस्त करता है। छोटे परिमाणों की स्केलिंग करके बड़े परिमाणों को समझना जटिलता को प्रबन्धित करने का एक अच्छा तरीक़ा है।

ii. **दोहराव :** पैटर्नों की तलाश करना, पैटर्नों के निर्माण और संशोधन के तंत्र ढूँढ़ना और नए पैटर्नों को देख पाना यह सब न केवल सुखद प्रक्रियाएँ हैं, बल्कि सौन्दर्यशास्त्र और औपचारिक तर्क के बीच एक जुड़ाव भी बनाती हैं। सरल नियमों को दोहराने की शक्ति को समझना न केवल कम्प्यूटेशन के लिए, बल्कि सिस्टम की गतिशीलता (system dynamics) को समझने के लिए भी आधार बनाता है।

iii. **डेटा व्यवस्थापन :** “डेटा हैंडलिंग” शब्द स्कूली शिक्षा के लिए जाना-पहचाना है, लेकिन यह केवल डेटा के आलेखीय चित्रण (graphical depiction) और संख्यात्मक सारांश (numerical summary) की कम्प्यूटिंग के रूप में समाप्त होता है। हालाँकि डेटा को कई तरीक़ों से दर्शाया जा सकता है और कब कौन-सा तरीक़ा चुनना है यह डेटा के उपयोग पर निर्भर करता है। इसके अलावा, डेटा के भण्डारण और पुनर्प्राप्ति के लिए मेमोरी संरचनाओं की आवश्यकता होती है। इस तरह का डेटा व्यवस्थापन डिज़ाइन करना स्केलिंग और पुनरावर्ती डेटा एक्सेस की समझ के साथ व्यवस्थित रूप से जुड़ा है।

iv. **मॉडलिंग :** वास्तविक जीवन की स्थितियों से समस्याओं की असतत मॉडलिंग (discrete modelling) स्कूलों में काफ़ी हद तक अपरिचित क्षेत्र है। सूचियाँ, फैमिली

ट्री, नक्शे, आलेख, जाली और नेटवर्क जैसी असतत संरचनाएँ आसानी से बन जाती हैं और कम्प्यूटिंग के लिए अमूर्त समस्या स्थान प्रदान करती हैं। शुरुआत से ही इस तरह की संरचनाओं के ठोस निरूपणों के साथ काम करने से मानसिक मॉडल बन जाते हैं और बाद में ऐसे मॉडलों की सहायता से कम्प्यूटेशनल अमूर्तीकरण में मदद मिल सकती है।

v. **एल्गोरिदम :** अंकगणित की बात करें तो दो अंकों के जोड़ से शुरू करते हुए स्कूली शिक्षा बच्चों को सीखने के लिए विभिन्न प्रकार की प्रक्रियाएँ प्रदान करती है— इतनी अधिक कि गणित या विज्ञान-शिक्षा अक्सर विशिष्ट संख्यात्मक डेटा पर लागू की जाने वाली पूर्व-निर्धारित प्रक्रियाओं को याद करने में ही बदल जाती है। एल्गोरिदम को समझने की दृष्टि से उनका *अनुसरण करना* निस्सन्देह लाभप्रद है, लेकिन प्रक्रियाओं को *विकसित करना* कम्प्यूटेशनल चिन्तन का मूल है। इसके लिए एक ऐसी सुविधा की आवश्यकता है जिसमें प्रक्रियाएँ, उनके बारे में तर्क, प्रक्रियात्मक विकल्पों पर विचार करना और एक स्पष्ट तर्क के आधार पर उनमें से चयन करना शामिल हो।

vi. **प्रोग्रामिंग :** दी गई समस्याओं को हल करने के लिए निर्दिष्ट प्लेटफार्मों पर डेटा व्यवस्थापन और एल्गोरिदम का ठोस कार्यान्वयन एक आवश्यक कौशल है। प्रोग्राम संरचना के भाव के साथ कोडिंग एक रोमांचकारी अनुभव हो सकता है, जबकि किसी दी गई औपचारिक भाषा में अनौपचारिक कम्प्यूटिंग के अनुवाद के रूप में कोडिंग एक कठिन अनुभव हो सकता है। इसलिए अन्तत: प्रवाह प्राप्त करने के लिए शुरुआत से ही प्रोग्रामिंग के लिए एक अच्छी मन:स्थिति बनाना आवश्यक है।

vii. **उपकरण :** कम्प्यूटर, स्मार्टफ़ोन और अन्य उपकरण कम्प्यूटेशन के लिए प्लेटफॉर्म और साधन प्रदान करते हैं। बच्चों को इन उपकरणों का उद्देश्यपूर्ण उपयोग सीखने और उन पर महारत हासिल करने की ज़रूरत है। साथ ही बच्चों के शारीरिक, भावनात्मक और बौद्धिक विकास के कारण इस तरह के उपयोग से उत्पन्न होने वाली कुछ चुनौतियों पर भी ध्यानपूर्वक विचार करने की आवश्यकता है। घोर आर्थिक असमानताओं वाले देश में ऐसे उपकरणों और प्लेटफार्मों तक पहुँच को हल्के में नहीं लिया जा सकता है। इसलिए इस सन्दर्भ में मार्गदर्शक सिद्धान्त है आवश्यकता के आधार पर सुरक्षित और सूक्ष्म उपयोग होना चाहिए।

viii. **सामाजिक जुड़ाव : सीटी** कई सामाजिक संरचनाओं, उनके संचार सम्बन्धी बुनियादी ढाँचों, पहचान निर्माण आदि को देखने के लिए एक अनूठा अवसर प्रदान करता है। इस प्रकार गणितीय औपचारिकता और समाज के बीच नए सम्बन्धों को गढ़ता है। अब, जबकि भले ही बच्चे सोशल मीडिया में तल्लीन रहते हैं और समानान्तर जीवन जीते हैं, तो भी उनकी शैक्षिक क्षमता काफ़ी हद तक अनदेखी रह जाती है। महत्त्वपूर्ण बात यह है कि विद्यार्थी समुदाय द्वारा भाषायी, क्षेत्रीय और अन्य बाधाओं को तोड़ने, डेटा निर्माण और एल्गोरिदम डिज़ाइन पर एक साथ काम करने की सम्भावनाओं को ध्यानपूर्वक जाँचने की आवश्यकता है।

ix. **सिमुलेशन और विज़ुअलाइज़ेशन :** फलनों के ग्रॉफ बनाना सीखना शायद स्कूल में **सीटी** का सबसे पुराना उपयोग रहा है। हालाँकि, जब बच्चे एक बार विज़ुअलाइज़ेशन और सिमुलेशन टूल के कम्प्यूटेशनल आधार को समझ लेते हैं तो, यह टूल विविध विषयों में पड़ताल के उनके क्षितिज का विस्तार कर सकते हैं। (अणुओं में परमाणुओं की बन्ध संरचना के साथ काम करते विद्यार्थियों पर विचार करें।)

इन सभी घटकों को पूरी पाठ्यचर्या में या सभी स्तरों पर समान महत्त्व नहीं दिया जाएगा। यह पाठ्यक्रम निर्माताओं का कार्य है कि वे प्रत्येक स्तर पर प्रत्येक घटक को प्रदान किए गए महत्त्व के बारे में बताएँ।

उदाहरण

मौजूदा स्कूली पाठ्यचर्या में सभी स्तरों पर **सीटी** के लिए शैक्षिक अवसर पहले से ही बड़ी संख्या में मौजूद हैं। स्कूली शिक्षा के प्राथमिक और उच्च प्राथमिक स्तर पर इस तरह के अवसर मुख्यत: गणित-शिक्षा में पाए जाते हैं। माध्यमिक स्तर पर ऐसे अवसर अध्ययन के सभी विषयों में अधिक विस्तृत रेंज में पाए जाते हैं।

हम क्रमान्तरण (reordering) और पुनर्समूहन (regrouping) की उन तकनीकों का पहले ही उल्लेख कर चुके हैं, जो अक्सर "मानसिक गणित" शीर्षक के दायरे के अन्दर आती हैं। इसमें गिनती की प्रक्रियाओं के बारे में तर्क करने के लिए भी कई अवसर हैं। उदाहरण के लिए, आप एक हॉल में हैं जहाँ पर बहुत-से लोगों (100 और 150 के बीच) की उपस्थिति में एक शादी हो रही है। आप वास्तव में यह कैसे पता करेंगे कि वहाँ कुल कितने लोग हैं? कैसे पता करेंगे कि आपने उन सभी को गिना है? आप यह कैसे जाँच पाएँगे कि आपका उत्तर सही है या नहीं?

छोटे बच्चों को चुनौती प्रदान करने के लिए 20 बीजों को गिनने के लिए कहना पर्याप्त है। चुपचाप गिनना बोल-बोलकर गिनने से अलग है, लेकिन क्यों? हम आसान-सा डेटा व्यवस्थापन देकर गुच्छे बनाने (bunching) और समूह बनाने (grouping) की क्रिया भी देख सकते हैं। जब हम बच्चे को उनमें से 15 को अलग करने के लिए कहते हैं, तो हम देख सकते हैं कि क्या उसे फिर से शुरुआत से शुरू करने की आवश्यकता है।

इस प्रश्न पर विचार करें : धनात्मक पूर्णांकों के कितने जोड़ों का योगफल 17 तक होता है? निश्चित रूप से इस तरह के जोड़ों को सूचीबद्ध करने के कई तरीक़े हैं, लेकिन तर्क की इस प्रक्रिया में सूची बनाने की किसी प्रणाली का उपयोग करना शामिल है ताकि यह सुनिश्चित किया जा सके कि सभी जोड़े गिने जाते हैं, और

प्रत्येक जोड़ी को केवल एक बार गिना जाता है। जब प्राथमिक स्कूल का कोई बच्चा किसी दी गई संख्या में 10, 100 आदि को जोड़ने का एक 'त्वरित' तरीक़ा प्रस्तुत करता है और यह जानता है कि यह तरीक़ा केवल इन संख्याओं के लिए विशिष्ट है, तो वह इस सन्दर्भ में **सीटी** का इस्तेमाल कर रहा होता है। एक नक्शे पर दो स्थानों के बीच कई "उचित" मार्गों को ढूँढ़ना, या अक्षरों की विभिन्न व्यवस्थाओं पर विचार करना, या विभिन्न रंगों के मोतियों से सौन्दर्यपरक रोचक पैटर्न बनाना, **सीटी** के लिए भी उत्कृष्ट अभ्यास हो सकते हैं।

इसमें डेटा निरूपण के लिए भी कई अवसर हैं। मान लीजिए कि महाराष्ट्र के एक गाँव में 61 परिवार मराठी बोलते हैं, 13 कन्नड़ बोलते हैं, 12 केवल हिन्दी बोलते हैं, 8 तमिल हैं, 5 गुजराती हैं और एक अकेला बंगाली परिवार है। इसके लिए एक तालिका बनाना निश्चित रूप से पर्याप्त होगा। लेकिन मान लीजिए कि हम प्रत्येक परिवार के लिए एक झण्डे का उपयोग करते हैं, जहाँ एक रंग एक भाषायी समूह का प्रतिनिधित्व करता है। तब हम इस जानकारी को कैसे दर्शाएँगे? झण्डे को 10×10 की तालिका में भी आयोजित किया जा सकता है, लेकिन रंगों का एक अव्यवस्थित वितरण मदद नहीं करता है। एक बार जब हम ग्रिड में रंगों को एक साथ समूहीकृत कर लेते हैं, तो अचानक से हमें न केवल एक समूह की संख्या के बारे में, बल्कि गाँव में समूहों के सापेक्ष आकार के बारे में भी बहुत सारी दृश्य जानकारी मिलती है। इसके बाद आयत चित्र (histogram) प्रस्तुत करना इस संरचना को और स्पष्ट करता है। यहाँ पर मुख्य बात सवालों के संख्यात्मक जवाब देने के लिए आयत चित्र का उपयोग करना नहीं है, बल्कि डेटा निरूपण के वैकल्पिक तरीक़ों पर विचार करते हुए उस तरीक़े पर पहुँचना है जो कि प्रश्नों के उत्तर देने के लिए सबसे अधिक उपयुक्त है। यही बात कम्प्यूटेशनल चिन्तन में डेटा संरचना का केन्द्र है और विद्यार्थियों को *कोड* (और त्रुटि सुधार) जैसी अद्भुत रचनात्मक धारणाओं के लिए तैयार करती है, जिनसे उनका परिचय बाद में हो सकता है।

सीटी के लिए आवश्यक दोहराव अन्वेषण के लिए एक उत्कृष्ट उपकरण प्रदान करता है। एक वर्ग के साथ शुरू करने पर विचार करें। मध्य-बिन्दुओं को आपस में जोड़ें। एक नया आकार बनता है, इस प्रक्रिया को दोहराएँ। यह सरल तरीक़ा आपको सुन्दर आकृतियों की ओर ले जाता है। जब विद्यार्थी यह जान जाता है कि यह प्रक्रिया अमूर्त है और किसी भी बहुभुज आकृति पर "इनपुट" के रूप में इसे लागू किया जा सकता है, तो यह **सीटी** के अनुसरण की शुरुआत होती है। तब हम टैसीलेशन, कोलम (या रंगोली) और फ्रेक्टल को दोहराव की प्रक्रिया द्वारा पैटर्न बनाने, उनकी विविधताओं के बारे में तर्क करने और इस तरह की समझ को औपचारिक रूप से सम्प्रेषित करने के अवसरों के रूप में देखना शुरू कर सकते हैं। फिर हम सीनियर स्कूल में समय के साथ भौतिक, जैविक और आर्थिक प्रणालियों में आए परिवर्तनों का वर्णन कर सकते हैं, जो दोहराए जाने वाले सरल समीकरणों द्वारा मॉडल किए जाते हैं और इन मॉडलों का उपयोग ऐसी प्रणालियों के दीर्घकालिक व्यवहार की भविष्यवाणी करने के लिए कर सकते हैं।

गणित-शिक्षा और सीटी

एक स्वाभाविक प्रश्न जो उत्पन्न होता है वह यह है कि क्या कम्प्यूटेशनल चिन्तन वास्तव में गणितीय चिन्तन से अलग है। वास्तव में, यह प्रश्न दार्शनिकों द्वारा सम्बोधित किए जाने वाले मूलभूत विचार से सम्बन्धित है, आप इसे स्कूली शिक्षा के सन्दर्भ में सीमित कर सकते हैं और यह दावा कर सकते हैं कि यह शैक्षणिक दृष्टि से दोनों को सार्थक रूप से अलग करने में मदद करता है।

इससे पहले कि हम इसे विस्तार से समझाएँ, थोड़े समय के लिए विश्वविद्यालय के गणित पर विचार करना उपयोगी है। वास्तविक विश्लेषण (Real analysis) में ऐसे उदाहरण प्रचुर मात्रा में मिलते हैं जो गणितीय चिन्तन और **सीटी** को अलग करते हैं। बोल्ज़ानो का प्रमेय (Bolzano's theorum) एक अन्तराल में एक मूल के अस्तित्व का दावा करता है जब एक सतत फलन (continuous function) में उस अन्तराल में विपरीत चिह्न के मान होते हैं। क्रमिक सन्निकटन की न्यूटन-रैफ्सन विधि (Newton - Raphson method) मूल खोजने के लिए एक कम्प्यूटेशनल विधि प्रदान करती है। ब्रोवर फिक्स्ड पॉइंट प्रमेय (Brouwer fixed point theorem) का दावा है कि किसी भी सतत फलन f के लिए एक कॉम्पेक्ट उत्तल सेट को अपने आप में मैप करने पर एक बिन्दु x इस प्रकार होता है कि $f(x) = x$। इस तरह के एक नियत बिन्दु की गणना एक चुनौती है और हमें एक सामान्य एल्गोरिदम के हाल ही में तैयार होने तक इन्तज़ार करना पड़ा। गणितीय कथनों और प्रमाणों की एल्गोरिदम (या रचनात्मक) सामग्री को निकालना एक बहुत ही दिलचस्प चुनौती है।

हम मानते हैं कि प्राथमिक विद्यालय के स्तर पर **सीटी** से गणित को अलग करना विशेष रूप से उपयोगी नहीं है, लेकिन गणित-कक्षा के भीतर **सीटी** के लिए अवसरों को उजागर करना प्रासंगिक है जैसा कि हमने ऊपर किया था। माध्यमिक स्तर पर इन दोनों को अलग करना उपयोगी हो जाता है। उदाहरण के लिए, n अज्ञात राशि वाले n रैखिक समीकरणों (पूर्णांक गुणांक के साथ) के एक निकाय (system) को हल करने पर विचार करें। हम ऐसा करने के लिए एक एल्गोरिदम सीख सकते हैं, जिसका नाम गाउस की विलोपन विधि (Gaussian elimination) है। फिर भी जब दिए गए निकाय का कोई हल न हो या एक से ज़्यादा हल हों तो हमें कुछ सहज-ज्ञान विकसित करने की ज़रूरत होती है। दरअसल, बाद वाली स्थिति में, हम यह पूछ सकते हैं कि क्या निकाय के अनन्त रूप से कई हल होने चाहिए। एक और प्रश्न मध्यवर्ती चरणों में उत्पन्न होने वाली परिमेय संख्याओं से सम्बन्धित है। क्या आगे काम करते हुए हमें उन्हें परिमेय संख्याओं के रूप में बनाए रखना चाहिए और परिमेय अंकगणित के साथ काम करना चाहिए, या उन्हें उनके दशमलव रूप में परिवर्तित करना चाहिए? क्या इससे कोई फ़र्क़ पड़ता है? समीकरणों के निकाय के लिए मैट्रिक्स प्रस्तुतिकरण का उपयोग करके हम क्या हासिल करते हैं? इस तरह के सवालों को उठाना और उनका जवाब देना **सीटी** के लिए आवश्यक है।

स्कूल में न केवल गणित-शिक्षा के लिए, बल्कि विज्ञान और अन्य विषयों के लिए भी **सीटी** की प्रासंगिकता है। डेटा को प्रमुखता देना, डेटा को गुणात्मक और मात्रात्मक रूप से समझना और डेटा की व्याख्या करना न केवल विज्ञान के लिए बल्कि भूगोल के लिए भी आवश्यक कौशल हैं। हालाँकि इस बात को कम महत्त्व दिया जाता है, पर यह कौशल इतिहास के लिए भी ज़रूरी है। ललित कला **सीटी** के लिए कई रचनात्मक अवसर प्रदान करती है और इसके विपरीत **सीटी** ग्राफिक आर्ट्स के साथ-साथ संगीत और नृत्य में भी शैक्षिक सन्दर्भों को बढ़ा सकती है।

सवालों को फिर से देखना

हालाँकि हमने चर्चा की है कि **सीटी** का क्या अर्थ है और यह स्कूली शिक्षा को कैसे समृद्ध कर सकती है, पर हमने इस सवाल का जवाब नहीं दिया है कि हमें ऐसा *क्यों* करना चाहिए। एक बात तो स्पष्ट है। ऑनलाइन शिक्षा और कक्षाओं में डिजिटल प्रौद्योगिकी के उपयोग की वकालत जिन आधारों पर की जाती है, वह उनसे काफ़ी अलग हैं जिनकी चर्चा हम यहाँ कर रहे हैं। हमारे कारण अलग हैं।

- *आलोचनात्मक चिन्तन* (critical thinking) विकसित करना शिक्षा का एक प्रमुख उद्देश्य है और एल्गोरिदम पर एक आलोचनात्मक दृष्टिकोण इक्कीसवीं सदी की आवश्यकता है। एल्गोरिदम तेज़ी-से हमारा जीवन चलाती है और एल्गोरिदम द्वारा डेटा कैसे बनाया और संसाधित किया जाता है इसकी परिपक्व समझ विकसित करने के लिए इस मूलभूत ज्ञान का होना आवश्यक है कि एल्गोरिदम कैसे काम करती है। इन प्रक्रियाओं पर महारत स्कूल के वर्षों में धीरे-धीरे विकसित होती है।
- शिक्षार्थी में *स्वायत्तता* विकसित करना शिक्षा का एक और महत्त्वपूर्ण उद्देश्य है। और कम्प्यूटिंग शिक्षार्थी को दुनिया को समझने के टूलकिट के लिए एक नया शक्तिशाली उपकरण प्रदान करती है। यह नया उपकरण न केवल बहुमुखी है, बल्कि यह उन क्षमताओं को भी शामिल करता है जो अभी तक स्कूल में अज्ञात हैं।
- *संसाधनों के बारे में चेतना* (*resource consciousness*) आधुनिक जीवन की एक महत्त्वपूर्ण आवश्यकता है। और जबकि यह एक पारिस्थितिक अनिवार्यता है, इस तरह की चेतना को स्थापित करने के लिए पारिस्थितिक रूप से संवेदनशील तरीक़ों से प्रयास करने की आवश्यकता है। औपचारिक चिन्तन (formal thinking) को भी इसी तर्ज पर पोषित किया जाना ज़रूरी है। कम्प्यूटिंग विज्ञान संसाधनों के उपयोग की स्केलिंग और जटिलता के प्रति संवेदनशीलता लाकर ऐसा ही एक नया अवसर प्रदान करता है।
- शिक्षा सामाजिक विकास में भागीदारी करने और विकास के मार्ग को निर्देशित करने के लिए नागरिकों को तैयार करने में *आधुनिक लोकतंत्र* की भावना को मूर्त रूप देती है। समकालीन दुनिया में नागरिकों द्वारा *डेटा*— वो सभी डेटा जिसमें वह शामिल है और वो सभी डेटा जो उसके कल्याण का निर्धारक है —*पर लोकतांत्रिक नियंत्रण* प्राप्त किए बिना ऐसा करना असम्भव है। इसलिए डेटा और लोकतंत्र के बीच के सम्बन्धों के बारे में नागरिकों को शिक्षित करना इस पाठ्यचर्या की एक अनिवार्यता है।

इस प्रकार देखा जाए तो स्कूल में **सीटी** शिक्षा का उद्देश्य स्वायत्तता और सशक्तिकरण के लिए कम्प्यूटेशन द्वारा लाई गई ज़बरदस्त नई क्षमता का उपयोग करना है। साथ ही डेटा और एल्गोरिदम पर एक आलोचनात्मक दृष्टिकोण विकसित करना और बढ़ाने (scale up) के अभ्यास के रूप में संसाधन उपयोग के प्रति संवेदनशीलता विकसित करना भी इसका उद्देश्य है।

यह उद्देश्यों के व्यापक कथन हैं। स्कूल में किस उम्र में क्या सीखना चाहिए इसका सबसे उपयुक्त निर्णय बच्चों के सीखने के मनोविज्ञान पर शोध के आधार पर लिया जाता है, न कि प्रौद्योगिकीय उपकरणों की उपलब्धता से। वास्तव में, डिजिटल प्रौद्योगिकी अपनी चकाचौंध वाली अभिव्यक्ति में मोहक हो सकती है। हमें इस बात को लेकर सर्तक रहने की ज़रूरत है कि बच्चे उपकरणों के गुलाम न बन जाएँ। इस तरह के विचार फिर से सुझाव देते हैं और जैसा कि हमने चर्चा भी की है कि प्रौद्योगिकी-आधारित **सीटी** की समझ की तुलना में **सीटी** और गणित-शिक्षा के बीच सम्बन्ध **सीटी** के लिए अधिक सुरक्षित और सार्थक अवसर प्रदान करता है।

अन्त में एनईपी चाहे जो भी वकालत करे और चाहे जैसे भी इसका क्रियान्वयन किया जाए, हमें यह पूछने की आवश्यकता है कि क्या हमारे पास शिक्षा-प्रणाली में सभी स्तरों पर **सीटी** का परिचय कराने की क्षमता है। शिक्षण समुदाय, विशेष रूप से गणित में, ऐसी सम्भावनाओं को लेकर जागरूक है और उन्हें शैक्षणिक संसाधनों के रूप में मदद की आवश्यकता है। *एसीएम इंडिया* की एक स्वैच्छिक पहल **सीएसपाठशाला**, जो स्कूलों के लिए एक पूर्ण **सीटी** पाठ्यचर्या [सन्दर्भ 2] प्रदान करती है और देश में लगभग एक हज़ार स्कूलों तक पहुँचती है, का अनुभव एक मज़बूत नींव प्रदान करता है जिसमें से भविष्य में कई पहलें शुरू हो सकती हैं। हम यहाँ इस बात पर ध्यान दिलाना चाहते हैं कि इस लेख में **सीटी** के बारे में प्रस्तुत अन्तर्दृष्टि काफ़ी हद तक *सीएसपाठशाला* के अनुभव से उपजी है।

तमिलनाडु राज्य बोर्ड की 2019 की गणित की पाठ्यपुस्तकों में **सीटी** पाठ्यचर्या के तत्वों को शामिल करने वाला एक *सूचना प्रसंस्करण* (information processing) ट्रैक शामिल है। शिक्षकों से इस पहल के लिए बड़े पैमाने पर प्राप्त सकारात्मक प्रतिक्रिया फिर से उम्मीद जगाती है।

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Endnote: This article is a translation of the English essay titled "Computational thinking: the new buzz" by R Ramanujam. It was originally published in the July 2022 edition of the Azim premji University (APU) publication *At Right Angles*. The Hindi translation has been very kindly provided to us by APU's translation archive Anuvada Sampada.

आर रामानुजम गणितीय विज्ञान संस्थान, चेन्नई में गणितीय तर्क और सैद्धान्तिक कम्प्यूटर विज्ञान (mathematical logic and theoretical computer science) में शोध कर रहे हैं। वह तमिलनाडु विज्ञान मंच से जुड़े हुए हैं और विज्ञान एवं गणित के लोकप्रियकरण और शिक्षा में सक्रिय रुचि रखते हैं। उन्हें विज्ञान को लोकप्रिय बनाने के प्रयास के लिए वर्ष 2020, इन्दिरा गाँधी पुरस्कार से सम्मानित किया गया था। उनसे jam@imsc.res.in पर सम्पर्क किया जा सकता है।

अनुवाद : निदेश सोनी

पुनरीक्षण एवं कॉपी-एडीटिंग : कविता तिवारी

सम्पादन : राजेश उत्साही

Aniket Gawade

Children working with computers in intervention schools of the nonprofit Universe Simplified Foundation

Problem solvers of tomorrow

Nurturing creativity through computing education in Indian schools

Shoaib Dar

A 14-year-old Ganesh Kumar, along with his classmates Anil and Arjun from City High School, have taken on the challenge of tackling frequent drainage blockages in Lambi Gali, a neighbourhood in Jammu and Kashmir's Udhampur district. The solution to create a real-time drainage blockage map occurred to them when a new teacher, Surinder, arrived from Pune and taught them how daily issues can be solved by inculcating critical thinking and technology. With a vision to improve the neighborhood's deteriorating condition, and with the curiosity to employ critical thinking, their solution has come to life! By using water flow sensors and LEDs, Ganesh and his peers have created a real-time map of the city's sewage system. Thrilled at their achievement, Ganesh says, "I want to be a teacher when I grow up...a good teacher helps improve society."

In a rapidly evolving digital age, where technology is at the core of nearly everything we do, preparing students for the future involves more than just teaching them how to use a computer. Computer Science (CS) education is no longer just about coding or understanding hardware. It is a medium that empowers students to become creators and problem solvers, regardless of their background or the resources available to them.

At Pi Jam Foundation, we try to ignite the innate desire of young minds to contribute positively to society, just as Ganesh did. Our CS curriculum tries to go beyond traditional methods, teaching critical thinking, design thinking, and collaboration—essential skills for tackling real-world challenges.

As the power of computer science continues to unleash, it only feels apt to explore the transformative power, its broad implications for learners, and groundbreaking initiatives together. We delve into a framework built upon five key principles that form the bedrock of our educational philosophy, uncovering how these principles are changing the way students perceive the world around them.

There are always challenges of tech misuse, cyber bullying and the risks it entails. This is particularly relevant for us as we work with children. Therefore, as part of our Let's Code program for children, we cover discussions on cyber safety, digital citizenship and the responsibility that comes with powers of creating with technology. For us, creative expression is invariably tied to ethical and safe usage.

Secondly, when a child perceives it as a tool for creativity, the outcome, for example, is that the animations our students share on social media are the ones they have created themselves, instead of becoming mindless consumers of social media. Besides, students also start operating from the space of solving problems they observe in their environment. This cultures a consciousness of creating to solve, and possibly to entertain, but never to create abusive content.

Computer science is a medium, every child is a creator and problem solver

Imagine a world where children are encouraged to be problem-solvers. The key lies in transforming education from a passive process of observation to an active one of engagement and empowerment. To unlock the problem solving and creative potential in a child, we need to adopt hands-on pedagogical practices that build these skills. By integrating practical problem-solving challenges and creative tasks into the curriculum, educators can guide students to apply their knowledge actively. Encouraging critical thinking, collaboration and experimentation fosters a deep understanding of one's problem-solving capabilities and creative potential.

In Wadgaon Sheri, students — Uzer, Raj, Sony and Arman — created a project called 'Walom.' It is an experiment to grow plants in a controlled environment. Walom addresses the problem of growing plants that require intensive human involvement by reducing the effort with the help of technology. "When we found out that we can use technology to address the problem and grow plants even in less space, we started to plan," shares Uzer. The students made a list of all the required components such as water, air, nutrients and sunlight. For every need of the plan, they appropriately used technology to fulfil it. The small space used was an old water-cooler recycled as a grow-box, which was fit for the project.

"We used artificial lights to mimic sunlight, fans to control temperatures, moisture sensors to detect soil moisture and indicate when to water, and an automated tap that sprays when the sensor prompts it to do so," explains Sonu. The students used Python to execute this project. From learning how to make circuits, work in teams, assemble wires, to 'fix' things, and to understand how programming works, the students had fun and learned computing skills that will go a long way.

They made mistakes. However, they overcame the challenges quickly, once they realized that they can work with complex systems. "We used to only read about these in the textbooks and never got to make these with our own hands. We have learned C++ but never experimented with it. But, when we

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came here, we did everything ourselves with our own hands," says one of the students.

The students worked over the weekends across six (6) months, turning the office into a makerspace. The absence of computer labs at their school premises birthed a wonderful and enviable project out of a noble idea. Moreover, providing opportunities for students to showcase their problem-solving projects and creative endeavours to peers, teachers, and the community, has boosted their confidence and reinforced their understanding of their own abilities.

Celebrating these achievements and acknowledging the uniqueness of each child's creative contributions can further solidify this understanding. At Pi Jam Foundation, we feel and see this impact every day. For the thousands of children that have been introduced to computing education, a world of possibilities has opened.

Every space can be a lab

When one thinks of a lab, the first thought is of complex science, followed by visuals of people seated in a specific order, typing as fast as they can while staring at the screen with numbers and alphabets running in all directions. Well, one isn't wrong to think of this set up as a lab. However, are labs only to be confined to four walls?

Every space can become a lab—be it a corner in one's kitchen, under the shade of a tree, or in a *gully* (narrow lane). Education in such spaces is often not recognized or encouraged. But an affordable learning ecosystem for computing education can equip even under-resourced neighborhoods and schools to build future skills.

A great example of this is Gully Gully Code. It is a student-led initiative, where former student leaders who have been with Pi Jam Foundation, and are now undergoing higher education, work with community children in neighborhoods and communities. Their goal is to introduce children to computing education. They go into community areas, like lawns, open dwellings, and spaces under trees, to mobilize the children from across the gullies to bring them together in one place.

These gatherings usually begin with simple games and activities that require a paper and pen, known as unplugged activities. In these, one needs to use logical reasoning, i.e., how do you move an object from point A to point B. It enables the children to think step-by-step, which helps them nurture their computational skills. Most children now have access to smartphones, which the student facilitators use for teaching them programming on the Code Mitra application.

These Gully Gully Code sessions are structured in a manner to allow at least an hour of app-based programming with the children who identify issues around them to solve. For instance, children in communities of Dharavi, Yerwada, Bhosari and other parts of India have identified issues of air pollution and waste management that affect their lives. With the help of Code Mitra, the children have successfully codified the problem and suggested simple solutions that can make the communities more liveable.

By breaking preconceived ideas of what labs are supposed to be like, children are now equipped to identify something that they relate with and create awareness to solve the problems at hand. Problem solving, computational thinking, logical reasoning, and collaborative experimentation are the bedrock of imparting computing education in spaces never imagined before. As long as the learners come together with a vision to solve a problem, they are collectively able to create a space for change.

Computer science is everywhere

For Adnan, Furqan and Shakir of Kashmir's Baramulla, familiarity with apple cultivation comes easily. While interacting with apple farmers, they were quick to identify that farmers were not compensated fairly for their produce. The reason being lack of access to Apple Grading Systems, which are expensive, with their cost ranging from ₹1,50,000 to ₹8,00,000. Their hope to improve farmers' profits inspired the trio from Government Higher Secondary School, in Kreeri, to design an affordable alternative.

Their research led them to leverage technology to create a prototype of an automated Apple Grading System. It uses servo motors and colour sensors to create an intuitive interface, which works on a real-time feedback mechanism. The technology grades the apples based on size, colour and other quality attributes. It also ensures accuracy and efficiency in the process. The prototype developed by the students costs about ₹60,000. Its comprehensive design allows for scalability and customization to cater to farmers' specific needs, based on farm size and production. The students also aim to upgrade the prototype by using solar energy to power the system.

This problem-solving design has helped streamline the labour-intensive process of grading the produce and ensure fair compensation for the farmers. Guided by their mentors, these students reduced the processing time and the scope for errors in the process. This means that the farmers can now procure an apple grader which is well within their means. It would allow them to focus on their production while increasing profits. Such innovations, even if they seem small, can create large-scale impact especially in a country like ours.

Computer science isn't confined to computer screens or the walls of IT companies. It's an integral part of our daily lives, from the patterns we observe around us to the logic we use in our everyday decisions. It's about pattern recognition, sequencing, and problem-solving – skills applicable in any context, which are centred on the individual's agency.

Over time, Pi Jam Foundation has diligently promoted problem-solving and computing education through initiatives such as Code Mela. This is an engaging program that introduces both students and educators to the world of computer science in a fun and interactive way. We utilize Code Mitra, a free, specially designed mobile app created for regional users.

In schools, these immersive, hour-long sessions, along with a holistic curriculum, enable computing education to be inclusive and accessible. It allows us to embrace the intersectionality of problem solving through logic, cultural reality, and everyday phenomenon. Many such initiatives have been recognized at the UN Education Summit, HundrED, Mbillionth, and other platforms.

You don't need a computer to learn computer science

Computer science education doesn't always need digital devices. In classrooms where electricity supply is sporadic, students are encouraged to think computationally without screens. They write code on paper, solving problems step by step. This 'unplugged' approach fosters logical reasoning and creativity. It also demonstrates that computer science is about the skills, not the gadgets alone.

In Mundhwa, on Thursdays, when there is an electricity outage, children unleash their culinary creativity. No, they don't necessarily cook. Without screens, they pick up pens, papers, and their boundless imaginations to whip up recipes, from savoury curries to sweet desserts. After jotting down their culinary masterpieces, they come together, sharing recipes and ensuring they're easy to understand. It's not a competition, but a lesson in empathy and teamwork. In this simple act, they demonstrate the power of creativity and collaboration, showing that even without electricity, the light of learning can still shine. Such unplugged activities help in building the foundations for logical reasoning and computational skills, which can be further honed based on the children's individual interests.

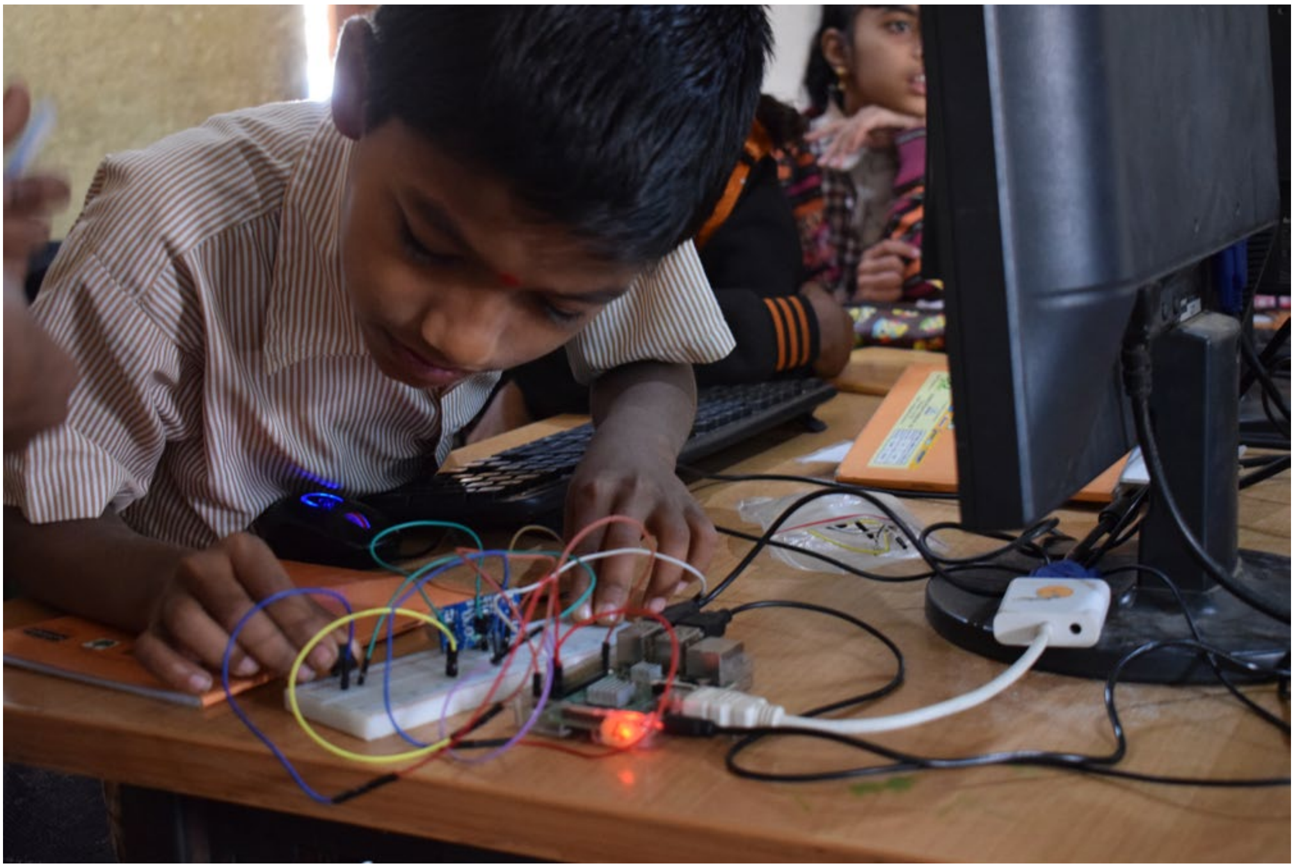
In another inspiring instance, consider the story of Humaira Jan, a ninth grade student. Learning from our Pi Jam trained Atal Tinkering Lab (ATL) teacher in Ganderbal, Kashmir, she applied the problem-solving framework to confront a deeply entrenched issue within her community. Faced with the limitations imposed by traditional customs, particularly those that adversely affect women, Humaira took it upon herself to become a catalyst for change.

She identifies that women in particular and people in general lack awareness. The question arises: why is there such a lack of awareness? The answer lies in the absence of individuals raising their voices and expressing themselves. Consequently, she makes the conscious decision to elevate her voice and express herself creatively through poetry. This vividly illustrates the concept of problem-solving coming to life.

Through her bold and innovative approach, she is emboldening women in her community to break free from the confines of societal expectations and embrace their limitless potential. Notably, her debut rap composition titled "Aurat" received well-deserved recognition. It was prominently featured on YourStory, a prominent storytelling media platform.

An approach based on systems, not a product

Education isn't merely a product but a comprehensive system. For widespread impact, you need more than just a curriculum. You need collaboration, support, and a multi-layered systems approach. While adopting such an approach, teachers and trainers play an integral role in ensuring that the spirit of problem-solving is instilled in children. The primary goal of Teacher Training (TT) at Pi Jam Foundation is to empower educators with Computational Thinking (CT) skills, so they can seamlessly incorporate these crucial abilities into their teaching practices.



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This approach extends far beyond technical subjects, adopting an integrated methodology. Its aim is to empower teachers, enabling them to effortlessly infuse CT skills into their regular teaching routines. An inspiring example of this approach is embodied by Yogita, an educator at a government school. Yogita is consistently dedicated to integrating CT skills into her classroom activities. She adeptly harnesses the teacher training framework provided by Pi Jam Foundation, effectively bridging the gap between block-based programming concepts and the everyday experiences of her students.

This approach enhances their conceptual understanding. It also facilitates practical application within the classroom. Yogita's unwavering commitment, coupled with the support of Pi Jam Foundation, has yielded remarkable results. Her students actively participated in a Code.org event, showcasing their CT prowess. We at Pi Jam Foundation played a role in this by offering comprehensive CT training, providing platforms to showcase her innovative teaching methods, and offering ongoing support through regular visits and refreshing training sessions.

The culmination of these efforts resulted in Yogita being honoured with the prestigious Ideal Teacher Award from Pimpri-Chinchwad Municipal Corporation (PCMC) for the academic year 2022-23. This serves as a shining testament to the profound impact of integrating CT skills on 21st-century abilities such as problem-solving, creativity, and critical thinking within her classroom.

While teachers like Yogita do their best with resources available to them, a rather disappointing observation emerges in many regions. Here, once-promising computer labs have regrettably transformed into virtual museums. This nomenclature stems from the stark reality that these facilities are seldom used, a disheartening testament to the underutilization of available resources. It also exposes the intricacies of incorporating problem solving, computational thinking, computer science, and creativity as tools into the current education system. It's not merely about introducing a novel subject. It also entails reshaping the very foundation of education.

The programs that we have developed at Pi Jam Foundation, emphasize on building teacher capacity, contextual toolkits and learning resources, and partnerships with the government at the national level, with NITI Aayog, and with education departments at the state and district levels. So far, we have developed more than 10 partnerships. From building teacher capacity to enabling the use of technology to aid learning, to using tech as a learning tool is a significant shift we are trying to bring, like the difference between learning to operate a projector or Zoom and developing computational thinking by learning to program.

In teaching a subject like math, for example, computational thinking helps understand and dissect the mathematical processes involved in teaching core math concepts. In science, they can create tools and models to help students visualize. So, these can become teacher learning materials that teachers can generate themselves.

We have also created a course module for computing in Marathi. This was launched with District Institute of Education and Training (DIET), Pune, and Samagra Shiksha. This module includes skills like design thinking and computational thinking.

When we talk in terms of shifts that have been brought about with these partnerships in the existing ecosystem, an example that comes our mind is from our work in the district of Baramullah in Jammu & Kashmir. During the launch of Mission Digital Baramullah there, the District Commissioner, who is a doctor, shared, "Even though I am a doctor I need problem solving skills." She was aligned and inspired with our vision when she saw our kids were not just applying technology but were applying problem solving skills to everyday problems.

Integrating our pedagogy and training into existing ecosystems like ATL labs, is yet another example. When the apple grader project was selected for the National Technology Week, right from the senior management to the DC to members of Niti Aayog noticed the project. The effort received impetus from local officers as well. There was a cascading effect. Other schools and teachers got inspired to nurture innovation at their levels too.

Last year we trained 50 master trainers. This year we are training around 1,000. This expansion is based on the existing and growing requirement from institutions. This is perhaps a sign that more of them are realizing that this exercise cannot be overlooked anymore. The training modules are also being integrated with the training of vocational subjects. The resource person has been engaged as part of continuous support and maintenance of these labs and has been officially incorporated as part of their existing KPI.

At Pi Jam Foundation, we are on a mission to democratize computer science education. We want to make it accessible to students across India. We believe that every child, irrespective of their background, is born with the potential to be a creator and a problem solver. By redefining learning environments, recognizing the ubiquity of computer science, promoting unplugged creativities, and adopting a holistic systems approach, we are trying to challenge the status quo of education in India.

Coding used to be relatively unknown for a large section of kids, except for a few private schools teaching the subject. Then the Covid-19 pandemic set in. Consequently, with online learning becoming ubiquitous, coding has become a part of everybody's imagination. What unfortunately remained out of that purview though were skills and meta-skills like computational thinking and logic.

NEP 2020 talks about problem solving, computational thinking, digital literacy, creativity and coding. However, what needs to be done is the integration of these policy imperatives with existing resources and policies of the government. For example, ICT CAL Mission would be happy if the labs were being utilized along with an appropriate and effective curriculum. So, we tied this elaborate work to the digital literacy movement, enabling us to battle this lack of holistic understanding of computer science.

When we started the organization, our idea was quite simple. We wanted to figure out learning, starting with a student, then to a teacher, a school, and then to a slightly larger ecosystem like a block or a district. We have progressively explored this as a clear hypothesis of what works at what level. In the beginning, while we were working with local governments and municipalities, we had initially not engaged with policy makers that intensively. We realized that it is best to directly and collaboratively work with the government to understand their needs, rather than do something in an isolated manner.

We preserve the experimental spirit. For example, we have tried to actively understand through our work, how community participation aids in student engagement and learning. We have also experimented at the level of scale. We have sought to experimentally address the lack of open, free and context-specific resources. Available resources are fantastic, but they are generally of a "global" nature.

The Covid-19 pandemic taught us that these tools are not compatible with the devices most of our children have access to, nor are they contextually appropriate. A child sitting in a village in Parbhani in Maharashtra, with no exposure to the western culture, was suddenly expected to relate to a Santa Claus walking across a path collecting donuts, for example. This did not at all resonate with the lingustic and cultural context for the child. This pushed us to create an opensource platform that was more relevant, contextual, accessible and comfortable. We aim to build this with NDEAR (National Digital Architecture) principles and protocols.

We are an organization that has progressively found itself working with all the layers of the education ecosystem. This means that we operate at depth to create high quality proof points. We operate at the meso layer with teachers, to create a community of model instructors and facilitators. We also work at the policy level, supporting state and government institutions. This has meant a lot of diversity within the organization in terms of working across these levels.

While this diversity in perspectives can be conflicting and challenging, we have tried to learn from this process. You have organizations either working at the policy level or with teacher training, or directly with students. However, at Pi Jam we see ourselves as a sandbox. We picked up a small problem statement. But we have tried going deep into it. This means constant learning as an organization, in terms of feedback from working on the ground and adapting to this feedback.

Students are at the center of this process. As the stories shared by us might have shown, our work has helped build the mindset of students towards better logic to interact with tech tools without fear. Our work with teachers has involved creating a community that can aid the district/block ecosystems. Decision making cannot be sporadic. It relies on the principles we have shared above.

Computer science education isn't just a subject. It is a medium that empowers the next generation to become critical thinkers, creative problem solvers, and active participants in a rapidly changing world, all the while learning technology through making. As we move further into the digital age, it is vital to ensure that students are not just users of technology, but empowered creators who can shape the future.

Shoaib Dar is the Founder-CEO of Pi Jam Foundation, a non-profit dedicated to providing access to affordable technology and fostering digital innovation and problem-solving skills among Indian students and educators. Pi Jam's work has impacted over 4.8 lakh students and 5,600 teachers across four states, with collaborations including NITI Aayog, Samagra Shiksha, and UNICEF.

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Broadening access and participation in computer science education across India

Divya Joseph and Bobby Whyte

Introduction

Over the past decade, the provision of computer science (CS) education in formal K-12 educational settings has expanded massively across the globe. As computing, AI and other digital technologies permeate our everyday life, many have argued that access to CS education should be expanded to equip young people with vital lifelong skills to thrive in the modern economy. Towards this end, CS has been increasingly introduced through school curricula in many countries. Where some countries have included CS in their curricula for many years (e.g., Poland, Germany and Israel), others have more recently included CS in state curricula (e.g., England and Sweden) or amended existing ICT (Information & communication technologies) curricula to incorporate CS (e.g., New Zealand). Likewise, informal CS activities have become increasingly popular in after-school clubs and libraries through initiatives such as Code Club and CoderDojo.

Broad challenges remain in access and participation in CS education, including a shortage of qualified teachers, understanding what should be taught and how, and fostering interest in CS education. In many states across India, socio-economic challenges and the lack of technological infrastructure have prevented young people from accessing CS through formal education.

In this article, we highlight three recent initiatives by the Raspberry Pi Foundation to broaden access and the importance of participation in CS education for young people across India.

Bridging the digital divide in under-resourced communities

India's digital divide is made worse due to a lack of access to electricity, the internet, and digital devices. In 2017–18, only 47% of Indian households received electricity for more than 12 hours a day and only 24% of households had internet access, with the figure dropping as low as 15% in rural regions. While it is not possible for an organization to single-handedly solve these access issues, we, at Raspberry Pi Foundation, are committed to moving the needle for young people that need access to digital literacy skills the most.

Through our partnership with the Pratham Education Foundation, we have adapted the Code Club program for learners from remote, underserved communities in Uttar Pradesh, Maharashtra, Karnataka and Rajasthan to facilitate learning coding and computing in their communities. Code Club is one of Raspberry Pi Foundation's flagship programs to introduce coding and computing to learners in a fun, safe environment. The informal 'club' nature of the program allows young learners, volunteers and educators to overcome the fear of coding and experiment using technologies.

Pratham provides local communities with infrastructure that includes tablets, Raspberry Pi computers connected to monitors or screens, and a WiFi connection. Learners aged 13-18 years use tablets and

Raspberry Pis to learn to code. We support the local staff at Pratham through training that helps them develop their skills on the basics of coding and programming pedagogy, so that they can facilitate sessions with young learners. During our training with the staff, young adults aged 18-25 years, we found that they were committed to organizing Code Clubs in their communities, and they wanted to use our training as an opportunity to upskill themselves as well. As a result of their feedback, we are now adapting our training to include additional programming languages like HTML and basics of Python, which the Pratham staff felt would improve their chances at employability.

Supporting non-formal CS education through partnerships

With many education systems around the world struggling to recruit and train adequate numbers of CS teachers, one challenge we want to address is existing teachers' confidence and understanding in teaching CS.

Since 2019, we have partnered with Mo School Abhiyan, an initiative of Government of Odisha (GoO), to support non-specialist high school teachers in government schools to run Code Clubs. As many teachers were non-specialists, we supported the teachers through online and in-person training sessions on the basics of Scratch, a programming language suitable for novice learners, programming pedagogy and how to run a Code Club. We also ran live-coding sessions every Friday. This gave an opportunity to interested teachers to clarify their doubts. The online sessions were supplemented through the creation of WhatsApp groups for regular support. By April 2023, over 950 code clubs had been registered. Four hundred and forty-three (443) teachers reported that they had run Code Club sessions. From this, we estimated that 32,000 young people had taken part in at least one Code Club session.

We were able to provide tailored support to teachers to develop their confidence and basic coding skills. However, we found many other systemic challenges during the implementation of the program. Since Code Club is an informal club program, teachers had to work with their head teachers to allocate time in the timetable. This proved challenging since some requirements of the timetable are dictated to the teachers by the state education department. Teachers have many non-teaching responsibilities as well. This made it difficult for them to make time.

In addition, teachers across the state continued to struggle with infrastructure issues. While the state government has mandated 10 computers for each school, most of the equipment is dated and not suitable for learning coding. This is a challenge for both students and teachers. The problem is further aggravated by intermittent electricity and internet access, making it difficult to access applications and resources online. Teachers also reported that once timetabled, they found that having just one session a week of 40 minutes was insufficient for students. Teachers seemed to be spending considerable time in revisions, as students were not getting sufficient time to practise as a result of the infrastructural issues at their schools.

For a robust CS program in schools, it is important that some of these issues are tackled at the state level. The scale of the problems makes it quite challenging for a non-governmental entity to solve these.

Adopting a school to pilot a computing curriculum

The insights from the community-led informal clubs program at Pratham and educator-led clubs program at the Mo School Abhiyan helped us design our formal computing curriculum for *Coding Academy*, a government-led initiative in Telangana in 2023. Our vision is to create a comprehensive computing curriculum that can be used in schools across the country.

Coding Academy is an institution established by the Telangana Social Welfare Residential Educational Institutions Society department (TSWREIS) to provide opportunities for children from economically and socially backward communities to learn coding and computing. Our partnership with TSWREIS involves creating and piloting a computing curriculum adapted to the needs of young learners in Telangana. The curriculum is delivered to the students by Raspberry Pi Foundation's instructors, who come with degrees and background in computer science and computing.

Over the course of the five-year partnership, we aim to identify non-specialist teachers at the Coding Academy. They will be trained and mentored by the instructors to deliver the computing curriculum. Moreover, we will work with the State Council of Educational Research and Training (SCERT) and other departments in the state to introduce the computing curriculum to government schools across the state.

Current and future state of CS education in India

Over 2.6 million students in India choose STEM subjects at the graduate level every year. STEM-related subjects and courses across the country have advanced, and have been refined, over the years. However, they still leave much to be desired, especially at the school education level.

National Curriculum Framework (or NCF) 2005 highlighted the importance of learning coding and computing. It spoke of the problem-solving strategies arising from computing and emphasized the place occupied by computers in the modern world. It acknowledged that bridging the digital divide in the country had to be prioritized before young learners around the country could be encouraged to learn coding and computing.

The pandemic further highlighted the need to bridge the digital divide. This has accelerated efforts by both government and private organizations to work towards bridging the gap. States like Delhi, Punjab and Pondicherry now claim to have computers and internet in more than 90% of their schools. This has created the potential to introduce a comprehensive coding and computing curriculum when ready.

NCF 2005 was also thoughtful in its approach in that it explicitly called out the difference between ICT and CS, while also stating that both had their place in school education. To use an analogy, while ICT is learning how to drive a car, CS is understanding how a car is built. In our experience of working with education departments and teachers across the country, we found that there is a tendency to use ICT, computer literacy, coding, programming and computing interchangeably. Most curricula across states seem to lay emphasis on computer literacy and some programming for higher grades. Unfortunately, there is very little focus on other aspects of computing and computer science.

The latest NCF (2023) does not seem to build on the thoughtful vision laid by NCF, 2005. Instead, it promotes technology only as a means to increase access to online resources, create localized content and potentially track learning achievements. The focus, therefore, seems more on students being competent but passive consumers of digital technologies rather than active, innovative creators.

Developing an understanding of CS and using technologies to solve real-world problems is key to economic and social change. There are many options for those who can afford private, expensive courses on coding and programming. However, for the underserved, low-resourced communities whose children study in government schools across the country, the options are limited.

The importance of learning computing is increasingly apparent. Even the renowned physicist Stephen Hawking recognized this when he said, "Whether you want to uncover the secrets of the universe, or you just want to pursue a career in the 21st century, basic computer programming is an essential skill to learn".

Apparent apathy from policymakers and their failure to think deeply about the skills required for children in the future has resulted in a lack of opportunities for children to learn these critical skills. As demand grows for graduates qualified in computer science, AI, and related fields (e.g., data science), there exists a current and pressing need to provide young people in India with opportunities to develop coding skills and to harness computing to tackle the problems of the future. Through our partnership work across India, we hope to advance this mission.

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Computational thinking in India

Aswin Jayakumar

Introduction

The Report of the Education Commission[1] of 1966, commonly referred to as the Kothari Commission report, opens with the profound statement, "The destiny of India is being shaped in her classrooms." Six decades later, the report continues to hold relevance. It once inspired independent India's first Education Policy, emphasizing the need for a science and technology-based education system to uplift the nation economically and socially.

Today, the world stands at the forefront of advancements in digital technology, including artificial intelligence, big data analytics, blockchain, and quantum computing. Once again, the future of the country hinges on its education system. National Education Policy (NEP) of 2020, India's first education policy of the 21st Century, aspires to instill a scientific temper in its students, in accordance with the Constitution of India, and to synthesize a system of education shaped by global technological advancements[2]. The objective is to create a workforce capable of thinking critically and solving problems independently.

Among the skills deemed essential by the NEP for students to thrive as capable, "innovative, adaptable, and productive human beings in today's rapidly changing world," the inclusion of Computational Thinking (CT) has sparked curiosity among the academic and technology communities. NEP 2020 mentions

Aniket Gawade

Children working with computers in intervention schools of the nonprofit Universe Simplified Foundation

CT twice, alongside skills like coding, digital literacy, and mathematical thinking, reflecting India's aspirations of becoming a global digital superpower. With the Information Technology (IT) sector set to increase its contribution to India's GDP from 7% in FY22 to 10% in FY25[3], the emphasis on CT signifies its relevance beyond just a career in IT.

CT is a problem-solving technique that mimics the processes involved in computer programming to obtain results beneficial for both humans and computers[4]. This technique equips students with pattern recognition, attention to detail, problem decomposition, and algorithmic thinking, enhancing their capacity to be inquisitive and independent learners. It is important to note that CT is not limited to students pursuing careers in Information Technology.

This article will not delve further into the definition and theoretical understanding of CT. Instead, the focus will shift to how CT is being integrated into India's schools and is benefiting students. While governmental efforts to advance the NEP's vision will be highlighted, notable contributions from the non-governmental sector to the public education system will also be considered.

At the policy level

Computational Thinking made its way into India's education policy for the first time in the Draft National Education Policy, 2019 (DNEP). It is noteworthy that CT is mentioned five times in the DNEP compared to two times in the NEP. The draft policy dedicated a separate section for Digital Literacy and Computational Thinking[5], recognizing CT as *a fundamental skill in the digital age.* It proposed the development of advanced-level curricula for CT and programming, with the National Curriculum Framework (NCF) responsible for defining the appropriate learning outcomes to be offered as courses in upper primary and secondary classrooms. Although NEP 2020 did not delve into the level of detail regarding CT seen in the DNEP, we see that the draft NCF has incorporated suggestions from the DNEP. Released in April 2023, the draft NCF for School Education has recognized CT as one of the capacities that mathematics education should foster in students[6]. The framework meticulously describes the curricular goals and competencies required to develop CT at the Preparatory Stage, Middle Stage, and Secondary Stage in Mathematics.

Samagra Shiksha, launched in 2018 as a centrally sponsored scheme that amalgamated the Sarva Shiksha Abhiyan (SSA), Rashtriya Madhyamik Shiksha Abhiyan (RMSA) and Teacher Education (TE) schemes, has been redesigned to align with the tenets of the NEP. As the largest centrally sponsored scheme in education, Samagra Shiksha is slated to play a crucial role in realizing the vision of NEP 2020. The Samagra Shiksha implementation framework[7], introduced in October 2022, places increased emphasis on CT and mathematics throughout the schooling years, starting from the foundational stage. The framework proposes the integration of CT education with the Rashtriya Avishkar Abhiyan (RAA), a scheme initiated in 2015 by the late Dr A. P. J. Abdul Kalam, Former President of India, which aimed at inspiring children between the ages of 6 and 18 years to learn science, mathematics and technology.

Atal Innovation Mission, another government initiative, aims to foster CT among young Indians. The mission is the flagship program of NITI Aayog. It promotes innovation and entrepreneurship. According to data from NITI Aayog, 10,000 Atal Tinkering Laboratories (ATL) have been established across 35 states and union territories of the country, as part of the mission[8]. A separate module within the ATL curriculum is dedicated to CT, highlighting its significance to the program[9]. The module covers topics such as introduction to CT, understanding circuits, flowcharts, algorithms, sensors, actuators and coding. To strengthen the effectiveness of the mission, NITI Aayog launched ATL Sarthi in March 2023. It is a self-monitoring framework for ATLs. It aims at enhancing their performance and promoting inter-ATL collaboration through the development of ATL clusters.

Implementation of computational thinking

Several states in India have initiated efforts to introduce computational thinking in schools, primarily through partnerships with civil society organizations (CSOs), universities, and Information Technology (IT) firms. It is likely that the launch of NEP 2020 has sparked these initiatives in the field of CT from the state machinery. Then again, there have been states like Andhra Pradesh and Tamil Nadu that recognized the significance of CT several years prior to the introduction of NEP 2020, formulating policies aimed at nurturing digital skills.

These state governments' partnerships with stakeholders have yielded positive results in the areas of curriculum development, establishment of model labs, training programs for teachers, and integration of CT principles into subjects such as mathematics and Information and Communication Technology (ICT). These efforts reflect a nationwide commitment to prepare students for the digital age and align with the vision outlined in NEP 2020.

a) Under the umbrella of Samagra Shiksha

With Samagra Shiksha playing a pivotal role in implementing the NEP, the administrative body of the scheme has actively sought collaborations to propagate CT across various regions of the country. For example, in the union territory of Jammu and Kashmir (J&K), a cooperative endeavor involving Samagra Shiksha, Pi Jam Foundation, Jammu and Kashmir Knowledge Network (JKKN), DIKSHA, and UNICEF resulted in the creation of Let's Code, a free course for students to learn computer science and explore computational thinking[10]. The course was made available on the DIKSHA platform for students and teachers, with an option for hands-on coding using the Code Mitra app developed by Pi Jam. The curriculum, developed by Pi Jam Foundation with inputs from Samagra Shiksha, JKKN, DIKSHA, and UNICEF strives for inclusivity and cultural relevance, particularly for the female students in J&K.

Similarly, in Gujarat, Samagra Shiksha and Gujarat Council of School Education (GCSE) joined forces with Tata Consultancy Services (TCS) to introduce the latter's CSR initiatives like "go-IT" and "Ignite My Future" across the state. The partnership is geared towards providing training in contemporary digital skills, including CT and design thinking, to students and educators[11].

In the state of Maharashtra, Samagra Shiksha Maharashtra, Maharashtra Department of School Education (MDSE), and Pi Jam Foundation have collaborated to instill 21st century digital skills in school-going students across 16 districts. This has resulted in the training of 5,000 teachers in digital skills and the establishment of over 100 model labs, implementing a culturally sensitive curriculum designed to empower 500,000 students with computational thinking and problem-solving abilities[12].

b) Collaborative ventures with the IT Sector

As some of the previous instances have shown, state governments have increasingly turned to collaborations with the IT sector to spearhead programs in digital literacy and computing education. In Uttar Pradesh, the state government has partnered with HCL Foundation and TCS to educate students and teachers in CT. In 2022, TCS signed a Memorandum of Understanding with the Social Welfare Department of Uttar Pradesh to introduce logical thinking, computational thinking, and STEM-oriented teaching in department-run schools. HCL Foundation has collaborated with the state's Education

Department to pilot a computing education program in 26 schools in Hardoi district. Its success has led the government to expand it to more upper primary schools in the state[13].

In Nagaland, the state's School Education Department has partnered with IBM India to introduce digital learning in over 250 secondary and higher secondary schools. The three-year collaboration aims to impact 12,000 female students through the "IBM STEM for Girls" program, an initiative by IBM India to promote education and career opportunities for girls. Additionally, non-profit organizations Quest Alliance and Youth Net have also signed on to this collaboration as implementation partners, tasked with training 1,400 teachers in instructional practices related to computational thinking[14].

Government of Odisha (GoO) has embarked on a venture with the International Institute of Information Technology (IIIT) Bengaluru, Microsoft India, and Vision Empower to implement the "Computational Thinking for Visually Impaired (VICT)" project in all the blind schools in the state. The project's goal was to enhance visually impaired children's access to science, mathematics and CT. The project's success led to its expansion to 100 schools across nine states in India[15].

Furthermore, in June 2021, GoO launched IBM India's "IBM STEM for Girls" program in 258 schools in the state targeting the development of master-trainers to enhance teacher capacity and align the state curriculum with the digital learning goals set by NEP 2020[16].

In 2018, Andhra Pradesh Department of Social Welfare adopted the curriculum of CSpathshala, an initiative of Association for Computing Machinery India (ACM India), in 188 residential schools. Additionally, 427 schools, part of the APSWREIS (Andhra Pradesh Social Welfare Residential Educational Institutions Society) network, embraced the CSpathshala curriculum, benefiting nearly 200,000 children. APWREIS' schools are part of a government initiative aimed at providing quality education to children of socially disadvantaged communities[17].

Moreover, Andhra Pradesh State Skill Development Corporation (APSSDC) has engaged in collaborations with industry leaders like Tally, Zoho, Amazon Web services, NSE Academy, InstaEMI, and Coursera to bring computational thinking and related 21st Century digital skills to school students[18].

Aniket Gawade

Children working with computers in intervention schools of the nonprofit Universe Simplified Foundation

c) Initiatives led by State Councils for Education Research and Training (SCERT)

State SCERTs have devised plans to incorporate CT in the state curriculum. Many states are in the process of crafting the State Curriculum Framework (SCF), with CT identified as a crucial component to be included.

SCERT Haryana conducted training for government school students, teachers and ATL instructors in mathematics education and computational thinking in 2022. SCERT Haryana, in collaboration with state representatives from the Technical Education Department and the Deputy Commissioner of Gurgaon, met with consultancy firms in Gurgaon to explore the establishment of an institute for emerging technologies, offering professional training in areas aligned with NEP 2020, including artificial intelligence, big data and blockchain[19]. Haryana State Higher Education Council has also prepared a "Ready Reckoner" on the NEP in 2020 to guide policy implementation, with a specific emphasis on incorporating Mathematics and CT into the state's educational goals[20].

Delhi's SCERT has introduced a revised curriculum for ICT education in classes 6-8, inspired by NEP 2020. The curriculum identifies CT as a core competency for students, featuring topics such as algorithm design and programming using Scratch, a free coding tool developed at MIT Media Lab[21]. Similarly, Goa's SCERT revised its ICT curriculum to encompass CT and 21st century digital skills[22].

Kerala SCERT, in 2022, included a dedicated chapter on mathematics and CT in a discussion note. It sought public opinion on the development of the State Curriculum Framework, highlighting its significance in the forthcoming state curriculum[23].

Tamil Nadu's SCERT partnered with CSpathshala to introduce digital learning and an advanced computing curriculum to the state schools. The unplugged CT curriculum by CS Pathshala became part of the mathematics curriculum in 30,000 schools in Tamil Nadu, starting in 2018[24].

d) Digital education within state startup initiatives

Some states have recognized the synergy between digital education and startup initiatives, capitalizing on the growing support for IT-based startup organizations nationwide. This approach benefits governments by leveraging IT firms' interest in supporting programs, viewing it as an investment in cultivating a technologically proficient workforce for the future.

"iStart Rajasthan" is the flagship initiative of Government of Rajasthan (GoR), designed to create a startup ecosystem and promote entrepreneurship. Under this initiative, the government has established "Techno Hubs" housing tinkering labs to nurture adaptive learning and CT among young entrepreneurs[25]. GoR also aims to instill an entrepreneurial mindset in school students through the "iStart School Startup" program.

Gujarat's Department of Education launched the "Student Startup and Innovation Policy (SSIP)" in 2017, followed by "SSIP 2.0" in January 2022, further promoting entrepreneurship and innovation among students. "Innovation and Entrepreneurship Hubs (i-Hubs)" have been established as futuristic, advanced technology labs to create an environment of innovation in Gujarat, to nurture young entrepreneurs and foster an environment of innovation in the state[26].

Kerala Startup Mission, the state government's nodal agency for entrepreneurship and incubation, distributed 50,000 electronic kits to schools to foster innovation and digital thinking among students. The "Kerala Infrastructure and Technology in Education (KITE)" initiative, a government-led effort, aims to bring digital education to government-run and aided

Some personal reflections

Years ago, during my time as a software developer, my primary focus was on the development of mobile applications intended for deployment on handheld portable devices. These applications were designed to assist agents in various settings, such as airports, shopping malls and restaurants. As with all software, reducing bugs was of paramount importance. However, the significance of the environments the applications operated in required them to conserve device memory and battery power and maintain stability. This required intensive code optimization, typically performed at the end of the development stage.

During the optimization process, developers engage in constant scanning of large code segments, breaking down complex portions, and reorganizing them to enhance algorithms and improve the application's speed and efficiency. Over time, programmers perform this constantly and consistently, developing a penchant for recognizing patterns and straightening knots in the code. The skill allows them to be programming language agnostic, reducing their learning curve when encountering new ones.

Extracting this philosophy outside the world of computers and imparting it to students is a complex task. However, achieving this opens a world of possibilities, empowering children to utilize this way of thinking to amplify their problem-solving abilities in various domains. To me, this is the core of computational thinking. While strongly associated with software programming, this skill has the potential to extend its applications to numerous fields beyond computers.

schools in the state, focusing on improving the quality of digital education through ICT, providing guidance to the government, and enabling private sector participation[27].

e) Partnerships with CSOs

Several CSOs have taken the initiative to engage with school students on digital literacy, CT, algorithmic thinking, and related topics. Some state governments have collaborated with these organizations to introduce digital education in their states.

As seen in Maharashtra, the state government engaged with Pi Jam Foundation to introduce 21st century digital skills through training and a tailored curriculum in schools. The collaboration led to initiatives like coding and AI themed Summer Camps, and Maker's Factory. At Maker's Factory 2023, over 150 students from partner schools in the state showcased innovative digital prototypes based on their learnings from the previous year. Pi Jam Foundation has also initiated a project supported by Capgemini, to partner with select local governments in Maharashtra, initiating digital education in their schools[28].

In Karnataka, the Rural Development and Panchayat Raj (RDPR) Department partnered with Yuva Chintana Foundation to launch the STEAM Education Program in 70 Gram Panchayat libraries in Yadgir and Koppal districts. This program offers hands-on and interactive learning experiences to foster higher-order thinking, CT, and problem-solving skills among young minds.

The program also aims to transform panchayat libraries into digital age learning centers staffed with competent instructors and equipped with advanced learning materials. Government schools in the districts are expected to collaborate with these panchayat libraries to enhance the program's effectiveness[29].

The School & Mass Education Department of Government of Odisha (GoO) partnered with Quest Alliance in 2020 to equip students with 21st century skills like digital fluency, CT and coding. The partnership has impacted 2,200 government high schools, benefiting 4,400 teachers and 300,000 students[30].

In Delhi, the government collaborated with She Codes Foundation, to teach coding, CT and logical reasoning to 1,000 sixth-grade girl children from government schools[31].

f) Government schemes and programs

Government of Goa (GoG) introduced the Coding and Robotics Education in School (CARES) scheme in May 2021. It targets government and government-aided high schools in the state, supplementing the existing syllabus with computational and design thinking skills, along with coding. A dedicated project management unit (PMU) oversees the scheme's implementation and is authorized to form Memoranda of Understanding with research institutes and technology industry leaders. GoG plans to establish training centers and research laboratories in each taluka across the state under the scheme. Lead schools in the state are designated to host robotics labs and deliver the CARES curriculum[32].

In collaboration with Amrita University, Government of Andhra Pradesh launched the "ASPIRE-TTT (Andhra Pradesh Schools Program Innovation for Research & Excellence – Train the Trainer)" program in 2016. ASPIRE selects and trains mentors to conduct workshops for 12,000 students in 40 schools in the state. It covers topics such as computational thinking, robotics, life skills, virtual reality, and cyber security[33].

In December 2022, Rajasthan Council of Secondary Education (RCSE) invited bids for supply, installation and commissioning of robotics lab in 300 government schools to promote ideation, design thinking, and computational thinking[34].

Other initiatives

CSpathshala, an initiative of Association for Computing Machinery (ACM), was established in 2016 with the objective of introducing computing as a fundamental science in schools. The organization has developed a well-designed CT curriculum and introduced it in schools across various states, along with relevant teaching aids. In 2018, the curriculum was piloted in more than 175 government and private schools in the states of Andhra Pradesh, Chandigarh, Delhi, Goa, Gujarat, Karnataka, Kerala, Maharashtra, Tamil Nadu, Uttar Pradesh and West Bengal. It benefited over 100,000 students[35] during its initial phase. The numbers grew to 400,000 students in 1,500 schools by 2022[36].

In addition to curriculum delivery, CSpathshala provides comprehensive orientation and training sessions focused on computational thinking and digital literacy. The beneficiaries of these sessions include state officials, officials from the SCERT, B.Ed. students, and teachers.

CSpathshala's expertise earned them recognition from National Council of Educational Research and Training (NCERT), leading to their active involvement in shaping the computer science curriculum for Grades XI and XII. The organization also played a pivotal role in offering insights to the education policy committee, emphasizing the significance of including computational thinking in India's educational framework. This culminated in some of the recommendations being incorporated into the DNEP.

In 2021, CSpathshala organized the Bebras India Computational Thinking Challenge for students and the Computational Thinking in Schools conference (CTiS) for teachers. The events saw substantial participation from both the student and teachers' communities and reflected CSpathshala's commitment to increase dialogue around computational thinking.

IBM India and CBSE (Central Board of Secondary Education) announced a partnership in 2019 to integrate an AI curriculum into grades XI and XII. The curriculum encompasses modules focused on knowledge, skills and values in Artificial Intelligence, with a strong emphasis on computational thinking. The curriculum, jointly developed by IBM India, CBSE, Australia's Macquarie University, Learning Links Foundation, and 1M1B, ultimately impacted over 5,000 students and 1,000 teachers across India.

Additionally, IBM and CBSE initiated the IBM EdTech Youth Challenge, a program designed to inspire students to leverage emerging digital technologies like AI and blockchain for the betterment of society. The partnership also gave rise to the 'AI for Better India' hackathon, where participating students were mentored by expert IBM mentors to ideate, develop and implement solutions harnessing the power of AI[37].

HT Codeathon, an initiative by Hindustan Times in collaboration with IT industry leaders like Acer and Intel, serves as a platform for children to learn and showcase their coding skills, while developing attributes like emotional intelligence, computational thinking, creativity and design. The program has established partnerships with the governments of Delhi and Chhattisgarh to introduce its learning modules in state schools[38]. In Delhi, the initiative has impacted 13,461 students from 1,000 government schools providing them with coding and programming skills aimed at developing CT and algorithmic intelligence.

Conclusion

The integration of CT into India's education system is a crucial step toward preparing students for the digital era. Several states in India have embraced the vision of NEP 2020 and are implementing CT initiatives in collaboration with various stakeholders. Through these partnerships and programs, students in India are being equipped with 21st century digital skills and empowered to become innovative and adaptable. The journey to fully integrate CT into education is ongoing. However, it holds immense potential for shaping India's future. This transformative endeavor is still in its infancy. It requires further effort from associated stakeholders to achieve NEP's aspirations and set the stage for a technologically advanced and progressive nation.

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Paper, scissors, code

A creative and affordable approach to learning computational thinking

Krithik Ranjan

Thinking like a computer (scientist)

Jeanette Wing defined *Computational Thinking* in her 2006 essay (Wing, 2006) as "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to Computer Science". This process of "thinking like a computer scientist" involves skills like *algorithmic thinking* or thinking procedurally in steps. It also involves *deconstruction* or breaking a problem down into small steps. *Abstraction*, or recognizing and generalizing patterns, is also an important part of computational thinking. So is *debugging*, which involves identifying and removing issues.

These skills are not only useful for computer programming but also for real-life problem-solving and other activities. Studies have shown that even very young children can grasp such concepts (Strawhacker, 2019). Early exposure to computational thinking (CT) can also improve a child's self-efficacy toward STEM (Science, Technology, Engineering and Mathematics) fields in the future (Ching, 2018).

Given the technological age we live in, CT has been identified as a fundamental skill that students should learn. India's National Education Policy 2020 has also increased the focus on CT in school curriculum through puzzles, games and coding (MHRD, 2020). Over the last couple of decades, a whole range of tools, kits and methods have been introduced in both academia and industry to promote and evaluate CT learning in students of all ages. However, what does it mean to learn CT?

There is no single, universally accepted definition and implementation of CT in curriculum. However, researchers have developed a few different frameworks to facilitate the development of CT learning tools and assessment techniques. One of the more popular frameworks was introduced by Karen Brennan and Mitchell Resnick (Brennan, 2012). This framework interprets CT along the three dimensions of *computational concepts, computational practices,* and *computational perspectives.*

Computational concepts are concrete concepts one learns when they program. These include sequences, loops, parallelism, events, conditionals, operators and data. Computational practices focus on the process of thinking and learning. These involves being incremental and iterative, testing and debugging, reusing and remixing, and abstracting and modularizing. Finally, computational perspectives explore the place technology and computing hold in the learner's life, like being able to express, connect and question through computing.

Learning computational thinking by making

In education research, it has long been believed that children learn effectively by designing and building things. Jean Piaget developed the theory of *constructivism*, arguing that information is not transferred directly from the teacher to the student. Rather, learning involves the construction of concepts in each student's mind. Therefore, an educator should not simply disseminate knowledge, but create an environment supporting the development of students' own mental models.

Seymour Papert further built upon this idea and defined *constructionism*, describing how building real, physical artifacts can make the learning process even more effective. These ideas of constructivism and constructionism have been the guiding principles for the development of CT learning methods and interventions. Researchers and educators have devised toys, tools and kits that enable students to learn CT by creating with CT.

One of the earliest approaches used to promote CT among students was LOGO programming language. This was developed by Papert. It enables learners to create graphics by giving commands to move a turtle on their screen (Papert, 2020). In recent years, Scratch (Resnick, 2009) and ScratchJr (Flannery, 2013) have been two popular block-based graphical programming environments for children. These helps create games and interactive animations on the web or with apps. These graphical programming interfaces provide a low technical barrier for learners by removing the need to learn complex code syntax.

However, these are limited to on-screen interaction. These are, therefore, less effective and engaging in settings where not every student has their own computer (Horn, 2007). In contrast, tangible programming tools enable multiple students to collaborate using a physical computational interface. Here physical objects represent programming concepts. These can be electronic robotic toys like Cubetto that children can program using tangible blocks. Alternatively, these may be non-electronic passive learning tools like board games (e.g., Robot Turtles).

Computing without computers

The cost and resources needed for both graphical and tangible CT tools make them less accessible for educational settings. These are especially infeasible for economically disadvantaged schools and communities, which may lack resources to maintain adequate computer laboratories.

In India, only 45% of the schools provide functional computers to their students (UDISE, 2022). Even schools that have computers, only provide limited and shared access to each student.

In our work at ATLAS Institute's ACME Lab at University of Colorado Boulder (CU Boulder), we have been exploring paper programming as an alternative to traditional CT learning interfaces. Paper programming leverages everyday materials like paper or cardboard, and computer vision algorithms, to offer an affordable and effective learning experience.

These systems are often mobile-based, which further reduces cost, as groups of students in classrooms can work on these paper programming activities with a shared smartphone. The domain of paper programming is still growing. Existing tools have shown promise in terms of learning and engagement.

The Kart-ON project (Sabuncuoglu, 2022) offers a paper-based programming interface for creative coding applications using p5.js, which is a beginner-friendly Javascript platform for creating graphical and interactive visuals. Students use

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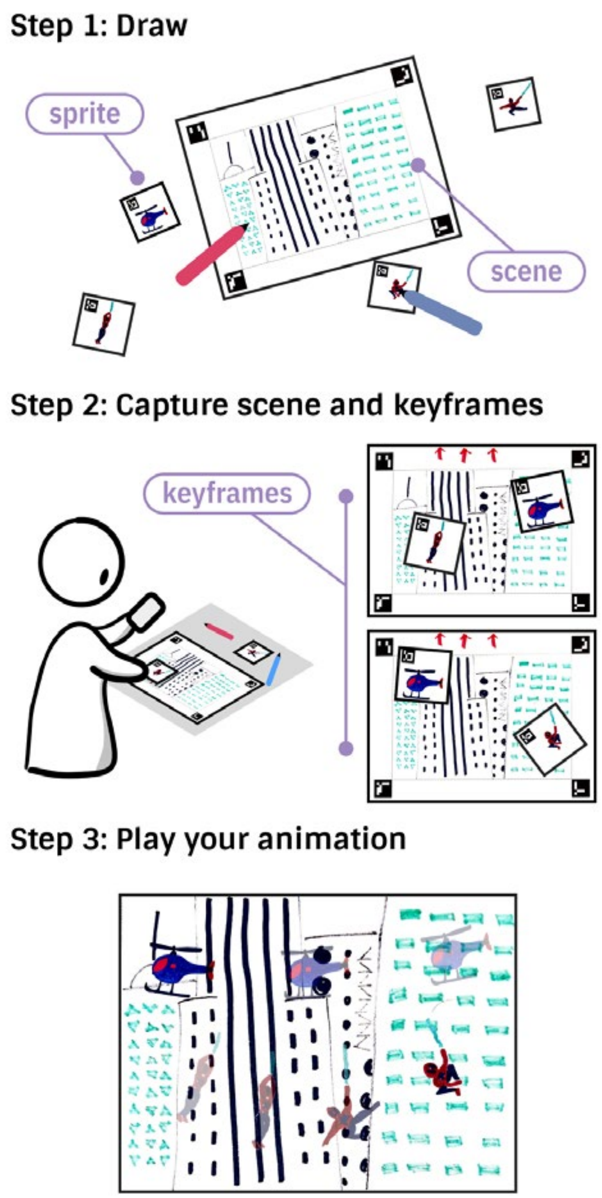
Paper programming interfaces: (A) Kart-ON, (B) Code Bits, and (C) Roberto.

programming cards for various functions and take a picture of the physical program to view the result on the phone. Roberto (Horn, 2013) takes a storybook approach in which readers can create their own animated stories by adhering code stickers to the book and scanning them to watch the animated character. Code Bits (Goyal, 2016) teaches CT concepts through an Augmented Reality (AR) app using a paper interface.

Paper-based animation with Cartoonimator

Building on this paper programming paradigm, we developed Cartoonimator, which is a low-cost paper programming kit that engages children with computational



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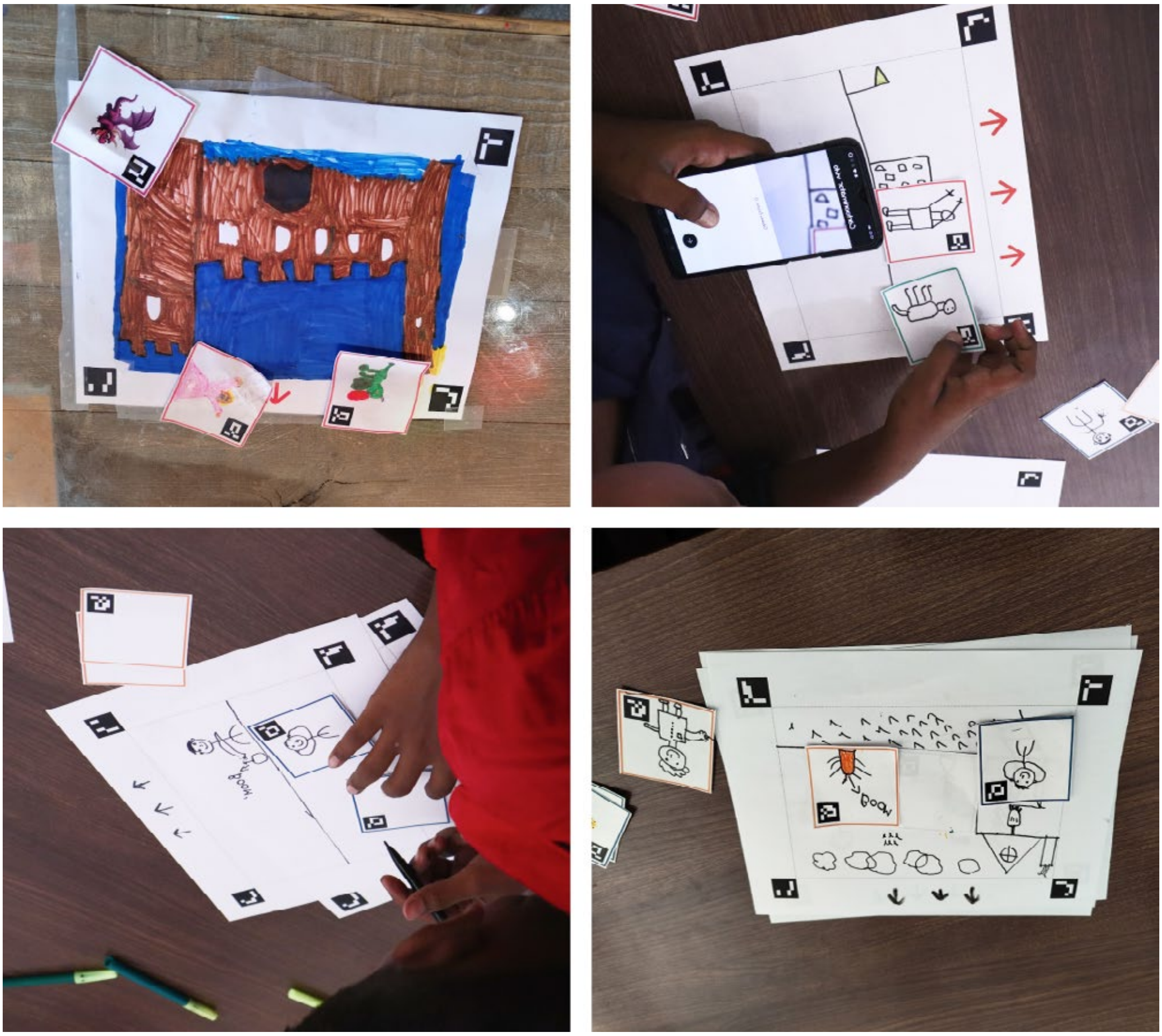
Creating an animation with Cartoonimator.

thinking through animations. Cartoonimator enables children to create animations from drawings or illustrations on paper, while learning CT concepts and engaging in CT practices. The Cartoonimator kit consists of paper printed with computer vision markers, and a simple smartphone app to capture frames and view the animation. The paper component of the kit consists of scene sheets for the background of the animation, and sprite card templates for the characters. Children can either draw on these sheets, or the instructors can provide pre-printed backgrounds and characters.

Cartoonimator features a technique called *keyframing* in which animators specify starting and ending points (*keyframes*) of a smooth transition. The software interpolates between them to create a complete animation. To create an animation with Cartoonimator, a child can place the sprite cards on top of the scene sheets to specify and capture different keyframes of the animation using the app.

An animation consists of multiple scenes. Each scene can have many keyframes with multiple characters. Children can move, rotate or even modify sprites over successive keyframes to progress the animation. After capturing a few scenes and keyframes, the child can play their created animation and download it to share with others.

Cartoonimator is open-sourced and publicly available. We encourage readers to try it out. The website includes the print templates, a link to the web app, and a set of instructions to create animations with Cartoonimator. We have deployed Cartoonimator with children between the ages of 6-12 in various informal settings and found it to be an engaging and enjoyable kit for children's creative exploration and CT learning. Our work on Cartoonimator and its deployment is in progress, and we hope this kit can be a step toward making computing education more accessible.



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Children creating animations with paper using Cartoonimator.

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https://commons.wikimedia.org/ Shri Ramswaroop Memorial Public School

Computer lab in a school

Happily bridging the computational thinking divide

Supriya Dey and Vaishnavi Gupta

"I see 10!" shouted Izin Jobins in an online Computational Thinking game session organized by Vision Empower and stole the hearts of the entire online audience at the Computational Thinking in Schools (CTiS) 2021 conference! They may have clapped from the confinement of their homes for this victorious little wizard, who convincingly won "I see 10", albeit without eyesight from a remote village in Kerala.

The T in STEM - unplugged

But you may wonder why we decided on games, and what do games have to do with computational thinking (CT) at all, especially for children with visual impairment.

The Vision Empower (VE) team works to make STEM education accessible for children with visual impairment by addressing the fundamental challenges of lack of accessible content, inadequate capacity among existing teachers of science and math at special schools and the lack of affordable assistive technology. In a digital age infused with electronic computing devices and software platforms, CT skills are seen as critical for everyone, and not only for computer scientists.

Jeannette Wing suggests that in addition to learning reading, writing and arithmetic, we should add CT to every child's analytical ability (Wing, 2006). Among other skills, CT entails thinking logically, recognizing patterns and abstractions, and understanding how to systematically decompose a problem and then compose an algorithmic solution. Wing argued that those in possession of computational competencies will be better positioned to understand and take advantage of a world with ubiquitous computing.

CT as a curricular topic

Computational Thinking made its way into selected Indian schools in 2016 when Association for Computing Machinery (ACM) India started CSpathshala, an educational initiative to introduce CT into formal school curricula in K-12 education and a vision to teach computing as a science to every child in every school in India by 2030. However, the visual treatment of the curriculum meant that the numerous CT lessons created through crowdsourcing from teachers were not accessible enough for children with visual impairment.

While CT was already being considered a mainstream requirement for sighted children at schools, the designers were oblivious of the needs of 1.1 million children with visual impairment in the country attending special schools for the blind. For decades, the students and their teachers remained unaware about Computer Science studies or the importance of problem-solving skills.

The journey of making CT accessible

The CT divide was observed by the VE team in the special schools for the blind during the pilot of accessible math pedagogies in middle school. The team began a research initiative on methods to bridge this gap, using tactile methods such as modifying playing cards or using pebbles of different shapes and sizes. The CSpathshala syllabus created by experts, is based on the four principles of CT – viz., decomposition, pattern recognition and generalization, algorithms, and programming.

These principles were applied to the learning areas obtained by combining the guidelines from the Foundations of Number

Sense (FONS) framework and the Indian NCF 2005 for Math and Computation. We created accessible CT learning modules on - Systematic listing; Counting and reasoning; Iterative patterns and processes; Information Processing (Data); Discrete Mathematical Modeling; Following and Devising Algorithms and Programming; and Digital literacy.

We launched Project VICT (Computational Thinking for persons with Visual Impairment) to make this curriculum accessible using the Ludic design for Accessibility (LDA) approach and thus initiated the students with visual impairment in India into CT early enough to equip them to participate in the digital age. LDA is based on the premise that play and playfulness are central to what makes us human. Play forms an important foundation for the development of skills in all children. Unfortunately, for infants and children with disabilities, real play may be absent or diminished due to accessibility concerns.

It has been pointed out that children with disabilities have a higher chance of being left out of play while they grow up, which may have serious implications on the cognitive development of the children (Swaminathan & Pal, 2018). Any ludic-designed artefact or activity must have five (5) attributes. The activity should be performed on free will; the player should gain no material incentive by playing it; it should be an activity that is within its specific boundaries of space and time; it should be an activity that promotes the formation of social groupings; and it should be capable of delivering the intended side-effect such as a particular skill or learning to the end user (for more information, please see here).

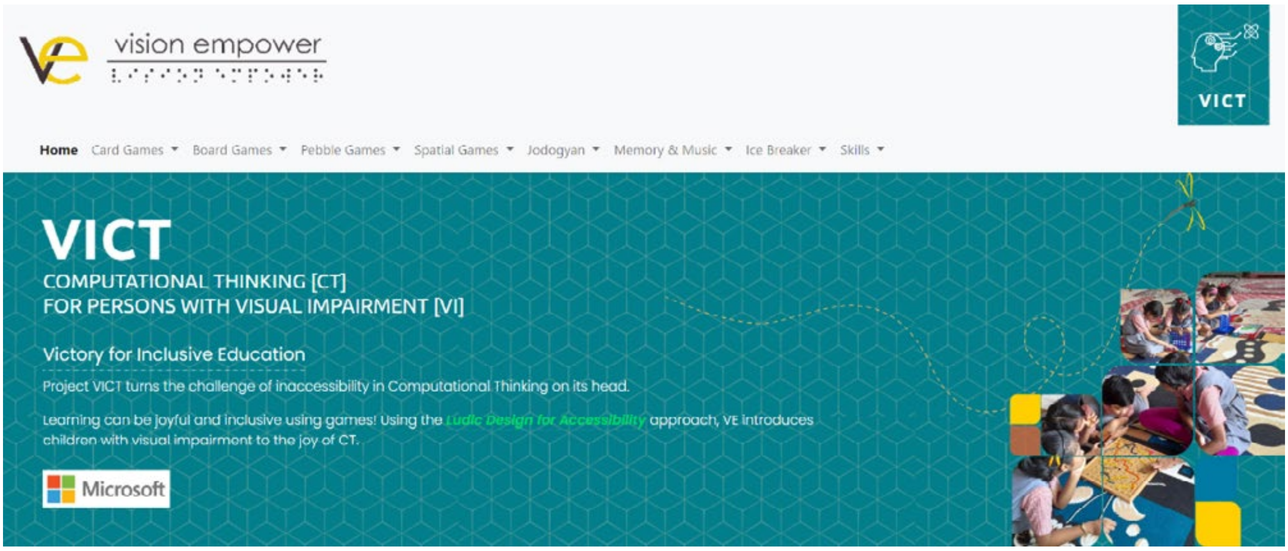
Playing the way to CT despite challenges

Recognizing the importance of ensuring that the methods result in learning outcomes which are easily comparable to proven pedagogical approaches, especially for numeracy in K-4, a rubric of Learning Areas and Learning Indicators were created for each game. We then focused on creating

Vision Empower

various games and tactile play kits which can be played remotely with minimal material requirements, available in all schools and homes. The VE team started by conducting weekly play sessions with children at the special schools. In 2019, we introduced the Torino tactile programming tool from Microsoft Cambridge as a pilot in Bengaluru. We were delighted to observe the joy in children with visual impairments playing their way to creative problem solving (Gesu et al 2020). The tool is now launched by Humanware as Codejumper.

However, the Covid-19 pandemic brought in new challenges as the schools were shut down and the children went back home. This led to the birth of a hybrid LDA approach where the VE coordinators got on phone calls with the children to conduct the play sessions while simultaneously training the teachers. After three years of continuous engagement with some children, the VE school coordinators and teachers in the schools shared that they have started to notice improvement in children in terms of their understanding on the fundamental concepts of numeracy, interest generation



Snapshots of the VICT page to highlight the different learning areas and learning indicators of CT. In addition to Subodha CT Courses.

and ability to solve problems in math through the various games they play as part of their VICT sessions, without increasing their cognitive load.

Changes ushered

Eight state governments have endorsed Project VICT. Teachers in special schools in 14 states have shown great interest in this pedagogic approach. VE was tasked by Government of Odisha (GoO) to create a Disability Innovation & Experience Centre based at Integrated Infrastructure Complex (IIC), Khudupur Experience zone at IIC (Inclusive I Center) for students and teachers. It is a space to showcase all the interventions and create programs to generate awareness and possibilities of inclusion in STEM education in general and CT in particular.

Having been continuously trained through VE's flagship Pragya teacher training program, teachers in these special schools are now equipped to conduct play sessions with children effectively, while helping them grasp the learning areas each game targets.

VE has been engaging with the broader CSpathshala community of practice of CT since 2021 and demonstrated the possibilities of inclusion in CT. It has also conducted workshops on inclusion in the pedagogy of CT, to the delight of hundreds of teachers from mainstream schools, faculty members from leading universities and industry experts at the CT in Schools (CTiS) national conference conducted by ACM India.

While capabilities of children with visual impairment were showcased by VE in CTiS 2021 along with an online participatory workshop demonstrating the "player" role of the teacher, VE conducted the Tactile and Accessible Computational Thinking (TACT) grand challenge in 2022 with entries from multiple universities and corporates. A compendium of tactile games has been curated with the ten winning entries.

There was a leap in the journey of inclusion in STEM education overall, when other than two abstracts from VE, six paper abstracts were submitted by 13 teachers from special schools across India to the CTiS 2023 conference. Eight teachers were selected as finalists. They presented their first ever academic paper at a national conference, a moment of glory for inclusive education.

Reminiscing the CT journey, VE's Educational Coordinator Rajeswari shares, "I started conducting offline sessions with children since Jan 2022. When I look back, I notice the progress in children in their communication, in their expression and comprehension, socializing skills and being sportive while playing. Their enthusiasm and joy in participation is palpable. I can also feel that they are learning while playing, which is the objective of Project VICT."

Project VICT is on the path of continuous improvement. Baselining assessments have been designed after rigorous secondary and primary research. These assessments are being conducted in schools across the country. Game clusters are being created through identification of dependencies in basic concepts, to help the children on a progressive learning trajectory. Besides, a new TLM on introduction to CT for teachers has been developed. This has been designed to help them understand the application of the games in the learning process. Our research suggests that the foundational CT concepts may be introduced to children as a part of an inclusive math curriculum to avoid cognitive overload and optimal utilization of school time.

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Voices from the ground

Heera Basnet

Pi Jam Foundation

Manisha Sakore, government schoolteacher, Late Appasaheb Dagadu Jadhav Primary School, Jail Wasahat, Pune

Today, children learn computer science with great interest. It is a need of the hour. Nowadays, every home uses technology in different forms.

Even in schools, computer science (CS) education is a very popular subject for students. It is relatively new. Students love learning it, as it gives them space for imagination and pushes them to think critically.

After receiving CS lessons, I have witnessed a shift in how students think. They have started thinking critically about problems, coming up with multiple solutions and selecting the best solution. They solve problems by relating them to daily life incidents.

In practical education, what we do daily is very useful for computer education. For example, the concept of sequence means that things are done step by step. If we use instances from everyday life, students understand computational concepts better. Programming language is similar. Students learn how improper sequencing can lead to errors or different outcomes.

Anjali Javale, government schoolteacher, Late Appasaheb Dagadu Jadhav Primary School, Jail Wasahat, Pune

Computer science is my favourite subject. I enjoy exploring and staying updated with new developments. I was very open to learning about Scratch when it was introduced. I wanted to explore what more we could do with the coding blocks. I experimented with different blocks and shared the experience with my students. The excitement to learn more about it further fuelled my interest.

Computer science is a practical subject; it requires hands-on experience. To achieve this, it is necessary for both teachers and students to have access to the learning resources. Without the right tools, theory falls short. Ideally, each child should access a personal computer, laptop, or tab, even if shared. These tools enable a transformative experience, crucial in the twenty first century, where computers are essential for the next generation.

As teachers, we witness many inspiring moments in our classrooms. One memorable occasion was when I introduced programming to a group of fourth graders. These young students were enthusiastic about sports and stories. They loved seeing the projects I created. When I guided them in programming on computers, they created impressive games, and they were fully engaged with the process. Seeing their excitement for innovation and creation felt amazing.

Shridhar Gavhane, government schoolteacher, Zila Parishad Primary School Nandgaon, Bhor

Getting kids to pay full attention in one place before teaching algorithmic thinking used to be quite a challenge. The students in the class are of different ages and have different ways of learning. When the classes are not engaging, some students start losing interest. But with computational thinking, something magical happens.

Students started getting involved in the lessons and enjoyed learning through animations and dialogues. They are excited to discover things themselves through computer science. Previously, students answered questions directly, but presently, they analyse questions and seek solutions. They don't fear making mistakes and take it as a part of continuous learning.

Through coding and programming, our goal is to cultivate a digital mindset among students. This is where design thinking, facilitated by coding, comes into play. Design thinking guides them in identifying the best path among various solutions. It empowers them to recognize a more efficient route towards achieving their objectives.

Heera Basnet works as a Program Manager at Pi Jam Foundation in Bengaluru. She hails from the hills of North-east India. She believes her work in the development sector has given her a space to align her passion and profession, while being a part of the change she wishes to see in the world.

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Fostering STEM education ensures an equitable future-ready workforce with an innovative mindset

Akshay Kashyap and Nirbhay Lumbde, in conversation with Pranjali Pathak and Ruchira Roy Chowdhury

When it comes to building the right ecosystem for good quality integrated computer science (CS) education in India, the private sector – comprising of NGOs and CSR bodies, among others – has played a pivotal role in supporting, enhancing and upgrading the existing infrastructure. It has also helped increase last mile access to technology and know-how, especially in the hitherto untapped rural and economically backward areas. But more needs to be done.

We chatted with **Akshay Kashyap**, *India Lead, Amazon Future Engineer* (AFE) initiative, and **Nirbhay Lumbde**, *Head, ESG at CGI*, to get their perspective as leading funding bodies/partners on what motivates their decision to support organizations working to improve CS education in India. We also discuss their criteria for selection, and some of the challenges and success stories that have come to inspire them in working with programs and foundations focused on bettering STEM/computing education in India?

Pranjali Pathak: As funders and donors, what motivated your organization to support initiatives focused on STEM/CS education?

Akshay Kashyap: Amazon is a company of innovators and creators. We realize that computer science has a huge potential to help shape the careers of the future. And while we do not generally believe that everybody needs to be an engineer, we think knowing computer sciences can help because any career they choose, can benefit from an understanding of computer sciences.

We know there is talent everywhere, but opportunity is not. And we want to use AFE (Amazon Future Engineer) to bridge that gap when it comes to computer science. We want to demystify technology for students, and make them curious about it. We feel we are very uniquely positioned to do that because of our understanding of tech and us being one of the industry leaders in that space.

We started the AFE (Amazon Future Engineer) program in 2019 in the US, as one of our first flagship education initiatives. Our goal is to support kids from underrepresented backgrounds in exploring and learning computer sciences. Another related objective is to provide the necessary support for those who want to build their careers in computer science. We analyzed similar challenges to solve in India. We realized that in India there are kids who are getting into computer science engineering. However, the data is not diverse in terms of representation of social strata or how many have access to computer science education in K-12 systems, particularly those in the public schools.

Nirbhay Lumbde: Our commitment to STEM education is deeply rooted in our belief in technology's transformative power. I have always believed that the future of India hinges on embracing the digital age. By championing STEM education, I see us not merely as funders but as catalysts, shaping the next wave of innovators and leaders who will spearhead India's digital journey.

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Ruchira Roy Chowdhury: What criteria do you consider when evaluating and choosing programs or foundations to support in the CS/STEM education space?

Akshay Kashyap: More than the organization we want to support, our focus has been on what is the problem at hand that we want to solve. Our leadership philosophy revolves around obsession with the end user. Our focus is on students from public schools. We ask, is this partnership or collaboration students-centric and how best does it benefit them? Will our engagement be an enjoyable experience for students? It's not just about learning outcomes, but are they really excited about learning?

We want to demystify computer sciences for students and have them interact with technology in a way they have not had access to, so far. So, we can bring real world computer science to students. That is the center of all our discussions, partnerships and funding. Our focus is on supporting the government school students and make more learning and growth opportunities available to those who have the least access to top industry resources.

In the school-based programs, our emphasis is on hands-on learning. Also, how sustainable are our partnerships? Are they scalable initiatives? Can they be integrated into a structure that already works, maybe the school education system, maybe some other channels that are already reaching out to students, or can they be integrated, and we keep increasing the level of support, but become sustainable in the long run? These are some of the answers we look for while looking for good programs to partner with.

We also look at what can we bring to the table, apart from the funding? How can Amazon support this partnership or the initiative through our employees, technology, resources and infrastructure? For example, we have organized multiple hackathons in our office, this year and the last, for children.

We have what we call class chats, in which our employees connect to students and talk about the careers that exist in the future and tell them about their own journeys.

Nirbhay Lumbde: Our five main criteria include –

Visionary alignment: Any initiative we consider must echo our overarching vision of nurturing a technologically adept and innovative generation.

Sustainability: We are drawn to programs with a clear long-term viability and a self-sustainability roadmap.

Inclusivity: It's paramount that the initiatives prioritize inclusivity, and ensure that girls and marginalized groups aren't left behind.

Innovative approach: We value programs that bring fresh, groundbreaking approaches to STEM education rather than just mirroring existing models.

Impact metrics: Clear, measurable outcomes are non-negotiable. We need to see the change we are creating.

Pranjali Pathak: From an industry/funder perspective, how do you believe supporting CS/STEM education aligns with your organization's values and long-term goals?

Akshay Kashyap: At AFE, our long-term vision is that every student should have access to computer science education. Like I said, we as a company are focused on, almost obsessed, with the end user and drawing from the same principle, our focus here is how we can help the student who comes from an underserved community with technology and empowerment through computer sciences.

This year we have introduced a new leadership principle that states scalability and sustainability brings broader responsibility. So, Amazon Future Engineers takes inspiration from the same philosophy. As a tech company, we are a company of creators and innovators. We've seen, and we believe in, the power of computer science to change the world for good. We can contribute to the community by improving access to quality CS education. This is very crucial because computer science will become essential in some sense or the other to every career that students pursue.

Everybody equates computer science with just coding. But the way, for example, we use technology in our company, in our logistics, in our sort centers, in the way stuff is getting delivered to customers, the way you are using data, to predict what is the right application of technology, goes beyond coding. And we feel, we bring immense value when we help students understand computer science as it is applied in the real world.

One of the things we have organized is the Amazon Cyber Robotics Challenge. Here children program a robot in a fulfillment center, where they virtually deliver a package to someone. Through this process, they learn that it is not just about punching out codes. This exposure lets them in on the real-world application of tech and computer sciences that invokes curiosity.

Ours is a three-tier program. We start with computer science exploration or real-world exploration, which is where our children or the students in AI-supported schools first go interact with computer science via an hour of coding. These interactions are also facilitated through unplugged activities which involve modules for a resource-constrained environment. Unplugged activities help students learn computer science principles without computers or the internet. This is where they get introduced to computer science, design thinking, logical sequencing, parallelism, structural problem-solving, among other things. This is the "Explore" level.

Then you move up to the second level – “Learn.” Whenever we see that there is interest among schools, or children, we support them with enabling deeper learning of computer science, where students end up creating a live working project. It could be a digital or physical project but uses computational thinking.

Then the last leg of our program is called “Build,” where we support students post their school education, to build careers in computer science.

We are trying to bring this pyramid together with, “Explore,” “Learn” and “Build.” Our goal is to support students from childhood to career while building curiosity and the right skill sets, and once they are ready, to help them transition into successful tech careers. Usually, we support organizations and partners, and co-create programs with people who help us build on this.

Nirbhay Lumbde: Championing STEM education resonates deeply with our core values. Being at the forefront of the Information Technology sector, we recognize the imperative of a robust foundation in these disciplines. By fostering STEM education, we ensure a future-ready workforce and nurture innovation and sustainable growth.

Ruchira Roy Chowdhury: Can you share some success stories or outcomes from projects that you have funded in the CS/STEM education domain?

Akshay Kashyap: It has been two years since the launch of AFE. Through this program we’ve been able to reach out to 1.2 million students across 7,000 plus schools, with 5.8 million hours of computer science learning behind them. Most of the schools we have worked with are in remote rural areas, including the Eklavya schools under the Ministry of Tribal Affairs and the Telangana Tribal Welfare schools.

We have also supported Karnataka State Education Residential Society that caters to the educational needs of students from marginalized sections of the community.

In Maharashtra, we have partnered with the State Education Department to train more than 7,000 teachers in CS modules. We have partnered with various district administrations to allow voluntary computer science courses. Here we have seen very high level of participation by teachers. And these are all teachers of math and sciences for younger grades, who are showing exceptional skill and interest in learning and utilizing computational tools in their teaching. This is being done in a scalable way, so that the government can replicate the model and build on the framework.

For example, somebody is teaching language using Scratch or Scratch libraries on Code Mitra (mobile-based platform built by Pi Jam Foundation to learn coding and application in the real world). Some teachers are integrating their CS learnings in mathematics and science and are asking students to make projects on topics such as photosynthesis using Scratch.

We have seen students build and innovate in ways that we did not imagine. For example, one of the students built a local weather system. Another wrote codes to automate irrigation pumps for farmers. Some other student made smart heater rods that monitor the temperature of bath water while the user finishes other chores. Some of our children, in an innovation lab in Mumbai, went on to build robots and participated in a global challenge in Switzerland. They were the only team from India. These were kids who had never learned computer science before in any meaningful way. It has been a revelation what bringing opportunity for those who have the talent, but lacked access, can do.

Our scholar internship program has 29% women, pursuing first year CS engineering.

We have supported 200 women scholars in the first year. We are supporting 500 this year. We offered fully paid internships (a gateway into Amazon) to 68 of them this year, based on a competency assessment. We support the scholars with a scholarship worth Rs. 50,000 per year for four years, along with a structured boot camp to help them acquire new and relevant skills. These girls who have interned with us, come from rural India and are studying engineering. They are role models for their own communities now.

Nirbhay Lumbde: Some of our success stories are incredibly inspiring.

National Recognition at NCSC: A prodigious student from one of the programs supported by us developed an ingenious automatic fertilizer dispenser. This solution showcased the practical application of STEM. It earned the student a gold medal at the 30th National Children's Science Congress (NCSC), a prestigious national science communication program spearheaded by National Council for Science and Technology Communication (NCSTC), in January 2023.

Spotlight at Rashtriya Bal Vaigyanik Pradarshani: Another testament to the talent we nurture is a student whose groundbreaking working model was exhibited at the Rashtriya Bal Vaigyanik Pradarshani, formerly known as the Jawaharlal Nehru National Science Exhibition.

Interaction with the Prime Minister: A cohort of young girls from schools we support presented their innovative solutions directly to the Prime Minister of India, at the Akhil Bhartiya Shiksha Samagam. Another group of talented students were handpicked to present at the National Technology Week Celebration, an event epitomizing India's strides in technological innovation and advancement.

Recognition by Government of Karnataka (GoK): CGI's commitment to STEM was spotlighted in a coffee table book titled "Impact of CSR Initiatives in Karnataka," which was unveiled by the Chief Minister and the Deputy Chief Minister of Karnataka. It's a matter of immense pride for us at CGI to be acknowledged for our "Magnanimity for Social Equity" through CSR by GoK.

Pranjali Pathak: What challenges do you foresee in scaling CS/ STEM education initiatives? How can these be addressed collaboratively between donors, governments and educational institutions?

Akshay Kashyap: We need CS to create the 21st century skills that will shape the future careers. There needs to be more appreciation of the need for foundational learning of CS, and not just CS but computational thinking, where kids are able to problem-solve using creativity and logic.

We all must work toward integrating CS systematically into the channels that serve students across the country in education systems, large non-profits, other platforms, etc. We must start introducing CS early on. It is not simple to remove the resource constraints from a country of the size and demography of India.

We need to be able to use innovation in problem solving. For example, we are taking computer science education to places without access to physical computers. We are doing this through the use of mobile-based applications like Code Mitra, Meraki or Chatbots that can run on basic mobile devices. We are undertaking unplugged activities for this purpose.

We also need to educate and inspire students about the wide-ranging career options that they have, thanks to these newly acquired computational skills from UX design to SDEP app development, and others.

Nirbhay Lumbde: Adequate infrastructure still needs to be developed in many regions.

And then there is educational quality. Upholding a consistent educational standard across diverse terrains is challenging. Some areas still resist contemporary educational methodologies. Talking about resource strategy, the challenge lies in channeling resources to the most deserving areas. There is a need for a unified approach. We need a harmonized strategy, bringing together donors, governments and institutions, which is the linchpin to surmount these challenges.

Ruchira Roy Chowdhury: What are your thoughts on the role of CS/ STEM education in fostering equity, inclusion and access.

Nirbhay Lumbde: Initiatives with well-defined inclusivity blueprints need to be prioritized. These may encompass scholarships for the underrepresented, outreach in underserved regions, and mentoring that encourages girls in STEM education and champions diversity. STEM education is a linchpin for equity, inclusion and accessibility. In today's digital epoch, proficiency in these domains is tantamount to literacy. By ensuring universal access to quality STEM education, we can level the playing field and empower students.

Pranjali Pathak is an engineer turned educator. Her passion lies in ensuring that the millions of students in our country, especially girls who leave behind harsh realities everyday to attend government schools, gain an avenue to develop 21st century technological skills that will propel them to a better future.

Ruchira Roy Chowdhury is a freelancer and contributor, and is a former banking and development reporter with *The Economic Times*. She is a New York University alumna, and has written for leading digital publications such as Indianexpress.com, NDTV and Youth ki Awaaz.

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Pi Jam Foundation

It takes two to tango

Teaching underprivileged children computing through digital literacy and computational thinking

A conversation with Venkat Natraj Ramasamy

Asha for Education - Chennai Chapter

Venkat Natraj Ramasamy works with Asha for Education's Chennai Chapter. Asha for Education is a volunteer-run nonprofit that has chapters around the world. Its mission is to foster positive social transformation in India. It attempts to do this by working on the education of underprivileged children.

Samuhik Pahal (SP): Please share with us the challenges of working on computing with underprivileged school children from remote, underserved villages.

Venkat Natraj Ramasamy (VNR): Asha for Education has 60 chapters across the world. I represent Asha Chennai. There are about 11 chapters in India, the rest of them are across the world. Most of the chapters outside India raise money. The chapters in India actually provide education.

I am only going to talk about Asha Chennai because each chapter is independent, and we do our own work. So, Asha Chennai focuses on remote rural villages. What we find is that most NGOs like to be in an area where they have their offices, or they operate in areas in which companies have their CSR operations.

We, however, work in remote rural schools in Tamil Nadu, which typically are not served by other NGOs, and in places that require the most help, because they don't have access to quality education. We have multiple programs. One of them being the computer science program. So, we have an Asha Computer Science (CS) curriculum. It goes from the first to the eighth standards. We want to get them early and we want to be able to separate the curriculum into two pieces. One is digital literacy and the other one is computational thinking.

In many developed countries digital literacy is almost automatic. Children there have access to computers, or they use smartphones. In many of the villages that we go to in India, many of the children don't even have access to phones. The parents are not wealthy enough to even buy a smartphone.

Therefore, we focus on digital literacy. In the first and the second standards, we introduce children to some basic keyboarding skills, usage of computers, mouse, etc., using games. We have a product called Asha Kanini, which we use to teach most of our courses. It contains about 80 packages that are all opensource. We have some of our own content, but mostly it fills gaps in the content. Most of the content is opensource, which we curate very carefully for each lesson in the government school curriculum in Tamil Nadu. We have also done this for UP, as we also support some schools in the state.

Our teachers use this curriculum to teach computer science in first-standard and second-standard classes. Some of the packages we use for the first and the second standards are from GCompris. Their opensource software is free for all to use, except for one or two things that we license for a very minimal amount. In the third standard we use Tux Paint, a free and opensource graphics editor, for digital literacy. We also use similar software to teach children math skills. And then we have a third item involving unplugged activities. This is where we start introducing children to computational thinking. These are activities that you can do physically that will teach you certain concepts in computer science.

Let me give you an example. Let us take one of the activities, like a grid activity where they have these tiles and we put obstacles in the middle, when we have a person standing out and there is a treasure. You tell the human being to go find the treasure, they can go find it. They can look at it and they can see the obstacles. The computer cannot do that. So, they have to say things like - they must walk a certain number of steps. So, sequencing comes in. Then if they see an obstacle there, they must turn left or right. Through this we teach them conditional statements. When they take a certain number of steps, we teach them looping. Through such processes we explain to them what those things are.

And so there are a lot of these kinds of unplugged activities. We have developed some of these. Some are created by others. There is a website created by University of Canterbury in New Zealand that has some of these activities. We use many of these to teach computational thinking in the fourth and the fifth standards.

SP: Before we go on to discuss details about your other initiatives in computational thinking, we request you to please elaborate a little more on the work that you do with children on digital literacy.

VNR: The purpose of digital literacy in our programs is to help children to not be afraid to take any computer software program or operate a new computer, etc. To do that they have to become quite adept at using these things. Therefore, we teach them how to use things like spreadsheets, presentations, Word documents, etc. For this we use an opensource software called Open Office, which is similar to Microsoft Office.

We also teach children how to search on the internet. They learn how to use the internet, how to access information, and how to use this information. And so that is what we focus on with digital literacy. For example, if they want to book a ticket or want to go do banking or something, then hopefully, they are not afraid to do so. We expect that the education we facilitate for them will enable them to just go ahead and say, “Oh, I can figure this out.”

Our focus is primarily on doing projects. So, what we have found is (and I am sure a lot of the research also says this) that when you just learn, you don’t retain all that all the time. However, when you do a project, you do retain quite a bit. So, at the end of the fourth and the fifth standards, our children are supposed to do a presentation.

These presentations, in terms of the project that they do, involve digital literacy skills rather than computational thinking. They use what they have learnt, do a project of their choice and prepare and show a presentation using all the tools they have learnt. We make sure they use custom animations, audio, video, and other things like that.

Some of the projects are on history. The presentations will have information about the industrial revolution or how the British came and how we got independence, etc. There are also presentations about their farming on different kinds of lands – these are the popular ones. Children do presentations on different kinds of dances, states and languages as well. They do a lot of those things. There are also projects on science subjects.

Many of our children, who have been with us for a very long time, (please remember that the children with whom we started work in 4th standard are now in 10th and 11th standards), they still remember their projects and presentations.

And so, whenever they do something like that, they have to go through a process when something doesn’t work, they have to figure it out. All these things give them the ability to go in, do research, explore and learn.

SP: When do children start exploring areas directly related to computational thinking and programming, etc.?

VNR: In the sixth standard we again focus a little bit more on the internet and then start programming using Scratch. In the 7th and the 8th standards we do mostly Scratch programming, and games and stories, etc., using the programs. And this year we are starting physical computing. So, we have a board. That has a heat sensor, a light sensor, things like that, which they use. They have LEDs that they can light up, they have sound; they can make that device talk. This is our curriculum from the first standard to the eighth standard.

For the 7th and the 8th standards they do a project using Scratch. And of course, this year there will be a project using the embedded systems board as well, which is more directly related to computational thinking. So, in the lower grades, our program is not directly tied to computational thinking, it is more to do with digital literacy. We don’t teach them programming on the computers. But we do computational thinking activities, the unplugged activities we have talked about.

All this work is supported by Asha Kanini, which is an application developed by us that helps teachers identify the right content for their lessons. It has an archive of freely available online content. We have mapped these to lessons for the various classes.

Asha Kanini is available on both Windows and Android. It has been designed with the requirements of remote rural schools in mind. It is independent of networks, platform, curriculum and language.

Asha Kanini is free for anybody to use for all the subjects. If you want to just use it, let’s say you want to talk about friction, for example. You can go and search for friction. It doesn’t have to be mapped to the curriculum. So that is available in English. Some of it is now available in Hindi as well.

The content of Asha Kanini is divided into three parts. There is content for teachers. Basically, the teachers must understand how they are going to teach the pedagogy. They will do that before they go to class. Asha Kanini also has content for students which is of two types - passive and active. The passive content just explains the concepts to them. So, it is typically a video or something like that. However, passive content is probably not the most effective way to communicate. But then they must understand the concept.

After we have taught them the passive content, we go into active content, which is basically simulations and games that they can play. Some of these games are very interesting. Children continue to do these repeatedly and as a result they remember the concept extremely well. This curriculum is for all the school subjects such as math, English, history and geography, etc. It is the same as what the government offers. We just support that curriculum using digital content. For all the schools that we support, we provide them with math kits, English kits, things that they can use to teach without having just a book, you know, they can touch and feel and be able to learn. If you are a teacher, we have lesson plans for every lesson.

Our computer science curriculum is also available as a part of Asha's website. Other than that, we support about 150 government schools in the lower grades in primary and middle school levels.

We also run a program called "Explore." Here we go to a particular school, three to four times a year. So, typically once a trimester, we go to these schools, and teach them basic digital literacy, basic programming, and a set of curated activities. These include the unplugged activities I talked about earlier, as many of these schools don't have electricity all the time. When they lose electricity, the best way to engage them is through unplugged activities. So, it usually takes about an hour.

SP: Thanks for sharing these details. The aspects of teaching and learning computational thinking and digital literacy that you have shared till now ride heavily on the government school system. Does Asha for Education have ways in which it directly interfaces with children in the communities you work in?

VNR: We run a project called an RTC, which is a Rural Technology Centre. It primarily targets students from 6th to 12th standards, who want to learn more advanced topics in computer science. Many of these children have never seen a computer before. Some of them need to learn digital literacy. In the RTCs there are also some of our children who have come from a middle school that we already support. For them we start teaching programming right away, because they already have digital literacy.

In the RTCs we teach computational thinking. We also teach them programming using Scratch. We teach them more advanced courses as well. Now we teach them animation using JavaScript, and we teach them web development. The goal is to help them learn how to write programs, create websites, use HTML, CSS and JavaScript, etc.

We also teach them physical programming, which is the board that I talked about. So, there is data science involved. We use data to figure out how the computer could start thinking a little bit more like a human being. So, these are the courses that we offer as part of the RTCs.

We rent some space within the villages, usually right next to the school, so that the children can walk directly to our centers. But some RTCs also support multiple schools. We have two teachers in the RTC. One of them goes to a high school close-by. The children come to us from these schools and even some other neighboring schools when they know about it. Now that we have been in many districts since 2002, many of the schools know about us. They send their children to us at 4.30 p.m. after the school is over. They stay at the centers till 7:30 p.m. to learn.

SP: What is the importance of collaborations and partnerships in your work in the computer science education space in schools?

VNR: We have a partner called code.org and we use some of their projects. Amazon is one of our main partners. They have curated one-hour activities as well. Then, we also have what is called a "Class Chat." In this program, typically what happens is that an employee from let's say Amazon will volunteer and talk to our children about their journey, how they became computer science experts, or even what other jobs that they might have at Amazon.

They talk about their own experiences, their own jobs, to just give the children a flavor of what it would be like when they go into the corporate world after education and stuff like that. Many of these rural children don't have access to that information. Everyone in their village is either farming or trying to do factory jobs.

This year we have selected about 50 schools in these remote villages. We will train government teachers to use our Asha computer science curriculum. We have curated a one-year curriculum where they will teach the students.

At the end of that, we plan to do a competition that we are calling "Impressions," where children would compete for the best presentations, best computer science programs, best physical computing programs, etc. We plan to provide a digital lab for them, maybe 5 or 10 computers for whoever the winner is. We will select the first three schools and empower them with more computers.

We also collaborate with higher education institutions like IIT Madras, and companies like Ford, Amazon and Hyundai, who support our intervention schools with computers and equipment.

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Transforming education

Government initiatives and collaboration for ICT advancement in India

Dr Vijay Borges, Dr Chintan Vaishnav and Shri Himanshu Gupta (IAS), in conversation with Maulika Kulkarni

When it comes to scaling up computer science education in a country as large and diverse as India, government stakeholders have an important role to play in terms of taking a renewed look at policymaking. These include overhauling of syllabus, introducing subjects relevant to the future, launching relevant initiatives to promote and provide computer science and future skills learning with wider access, and meeting the economic and geographical challenges.

We had the opportunity to interview Dr Vijay Borges, Project Director, Project Management Unit, Coding and Robotics Education in Schools Scheme (CARES), Government of Goa; Dr Chintan Vaishnav, Mission Director for Atal Innovation Mission (AIM); and Shri Himanshu Gupta (IAS), Director of Education, Government of NCT of Delhi. These officials have played critical roles in the education landscape broadly, and in computer science and future skills learning specifically. In this piece, we discuss with them the challenges, milestones and the road ahead in making Indian education future ready through computing education.

Maulika Kulkarni: Can you please share some insights into the various initiatives and policies undertaken by the government to promote access and learning in computer science (CS) and technology education?

Dr Vijay Borges: In response to the growing importance of computer science and technology education, we have launched several initiatives and policies to enhance access and learning in these fields. The journey of Coding and Robotics Education in Schools (CARES) Scheme, Goa, started in 2021, a few months after National Education Policy (NEP) 2020 was drafted and presented. NEP 2020 is divided into three parts — school education, higher education, and skilling education. NEP 2020 emphasizes three critical aspects: computational thinking, design thinking, and mathematical thinking. Rather than treating subjects such as mathematics, social sciences and art in isolation, it emphasizes the need to view them collectively.

This holistic approach aligns with 21st-century skills, emphasizing collaborative efforts, cross-disciplinary knowledge integration, and horizontal thinking. The goal is to nurture a child's thinking abilities through innovative and experiential pedagogical approaches.

In January 2021, approximately 6 to 7 months into this journey, the coding and robotics program (CARES) was conceived. This initiative aims to inculcate computational and design thinking into the educational framework. It seeks to encourage diverse thinking approaches when addressing problems. Instead of compartmentalizing subjects, the program shifts towards a holistic approach. This includes considerations like abstraction, algorithms, and the merging of various elements to provide a more comprehensive learning experience. The ethos of the program lies in the pursuit of problem-solving and the development of practical solutions.

Dr Chintan Vaishnav: The larger vision is to cultivate a million neoteric innovators — people who will have the capacity to navigate uncharted territories. In hindsight, there are two things. First, there wasn't a grand epiphany, and second, the Atal Innovation Mission (AIM) was announced in the budget prior to which there was some brainstorming.

The early ideas of launching Atal Tinkering Labs began with a good accidental encounter with a paper that discussed ideas such as "If you were given x amount of money, what would you do with it?" A lot of brainstorming took place before a person suggested giving 3D printers, which is what led to conceptualizing this makers' space called Atal Tinkering Labs. Over time, it has grown to incorporate design and computational thinking.

When you look at school labs, there have been two waves before the makers' lab wave, the science labs wave and the computer labs wave, which are very different from each other. The makers' lab was possibly the first time that both minds and hands are involved. In science labs, they prove what is known, in computer labs, they digitize what is not digital, and in makers' labs, they create thoughts!

Shri Himanshu Gupta (IAS): The Indian education boards' curriculum predominantly emphasizes theory and the existing subjects. For instance, after grade 10, if a child wants to study science, they take math, physics, chemistry or biology, and the other options to study are commerce or arts. However, these subjects are not necessarily equipped with 21st-century skills and appropriate assessments. In Delhi, we have undertaken an overhaul to redesign the entire curriculum, which includes subjects like Coding, Robotics, Digital Media and Design. This enables us to introduce coding as a subject which can be taught to grade 11-12 students and assess them as well. In addition to the introduction of these subjects, the Board has also designed assessments that can appropriately test for the skills that are required to master them.

At present, we have a tie-up with Indian Institute of Technology Delhi (IIT Delhi) and I-Hub Foundation for Cobotics (IHFC) to develop a specific curriculum for coding, which will cover important topics like artificial intelligence and machine learning. The syllabus is designed by IIT-Delhi, and assessment is done by the Delhi Board of School Education (DBSE). Similarly, we are bringing new high-end 21st century skills – like film and media making, robotics, automation, automotive courses, fashion and media design courses, and fashion technology courses – to schools. We are also redesigning our courses in partnership with Tata Institute of Social Sciences (TISS) and Ashoka University. We have engaged a lot of players to redesign our courses, in tune with the National Education Policy (NEP), which cater to the current needs of the country. Earlier, other boards encountered a challenge where they had the curriculum but lacked proper assessment methods. However, in Delhi Board of School Education, we have taken the initiative to implement assessments in line with the philosophy of the International Baccalaureate, addressing this issue. This marks a revolutionary shift from the old regime.

Maulika Kulkarni: How does the government plan to scale these initiatives and ensure widespread participation, especially in underserved areas?

Dr Vijay Borges: We are a small state, which is advantageous. I worked closely with our previous Chief Minister, who believed that Goa could be an experiment for the entire country due to its small size and population. Unlike an urban-rural divide, Goa is more like an urban city spread across villages. We primarily focused on 460 government and government-aided schools, not private institutions, all under the State Board. These schools cover various subjects such as science, math, social studies and art. We decided to tackle the issue by working through modifying "computer awareness," a co-academic subject that already existed and has a familiar sound to it. Since it was not an academic subject, it provided us with flexibility for experimentation.

Our challenge was revamping the entire curriculum, which required aligning with NEP's 5+3+3+4 structure. We concentrated on the second '3', focusing on middle school (6th, 7th, and 8th grades). In hindsight, was it the right idea? We realized the importance of the first three years, as foundational skills like mathematics and logical thinking are crucial for later development.

The Foundational Literacy and Numeracy literature shows that the first 3 are also very important, because if the child has not caught on to the mathematical skill or the logical thinking skill set, then it becomes challenging for them to catch up as time passes.

Another challenge was building teachers' capacity. While training in-service teachers, we recognized that many lacked a background in science. Therefore, instilling confidence in them was important for the scheme's success. It may be noted that scepticism often surrounds government initiatives. This leads to a challenge in engaging a multitude of stakeholders. In our case these include, 300+ private management (aided institutes) and 160+ government institutes, 600+ teachers and 65,000 odd students along with their parents. The launch of the scheme in 2021 coincided with the peak of the COVID-19 pandemic. This presented its unique challenges as this curriculum was envisioned to be hands-on, which now had

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to be done maintaining social distancing norms.

To gain confidence of the stakeholders, we had to visit and conduct meetings with the managements of 460 schools in all the 12 talukas of the state. The roles of all the stakeholders had to be clarified. Confidence had to be built in delivering the scheme to the end users. We were agnostic whether it was a rural or an urban area. Our approach was practical and worked on continuous feedback from the stakeholders. This helped us meet the expectations of all the stakeholders. This has been a major success over the last three years, since the launch of the scheme.

Dr Chintan Vaishnav: I think this program remained open from the get-go, so there weren't any restrictions on the schools to apply. It could be a private school or an urban school. There needed to be certain criteria: space availability, which grades, whether there is a science teacher, and things like that. But otherwise, it was open to all. Over time, as the numbers grew, there has been a nudge to stratify sampling so that they are somewhat representative of what the landscape looks like. Now 60% of the labs are in rural areas and 70% of them are in government schools.

The next milestone for us that we have proposed is 70,000 or 1 in 3 schools. There is also some calculation behind it. If you see

the proximity of schools, then one in three is still within the same block. So that was the thinking. It took us five years to build 10,000. So we can't imagine that to be the model for fulfilling our aspirations in the next five years. Because sequentially we will only be reaching another 10, but we have to parallelly build. So, our proposal is that we build through states and the private sector.

Shri. Himanshu Gupta (IAS): We want to go a bit slow and steady in this. The curriculum we have designed is being implemented in 40 of our government schools. Currently the curriculum is being vetted by industry experts. Once the process is over, we will look into expanding it to all our schools. We will open it for private schools also, who wish to come to our Board to apply for it and take the courses. We are also exploring partnerships with universities such as the prestigious Delhi University to ensure that the students don't face any difficulties in the application process.

The impact on these schools is visible. We recently organized the Delhi Robotics League (DRL). DRL is a statewide robotics competition for school students. The competition was open for all the schools of Delhi, whether private or government. It is noteworthy that bootcamps with the help of IIT Delhi were organized in schools across Delhi. In the top 16 teams, nine teams were from government schools, and seven were from private schools. The winning team was from one of our Specialized Schools. And they defeated some well renowned private schools of Delhi like Springdales School and DPS RK Puram. So, you can see the prowess of the students. What they have been able to achieve is inspiring.

Maulika Kulkarni: With multiple government pathways and approaches to CS education, how do you ensure a cohesive, standardized and adaptable frameworks for learning?

Dr Vijay Borges: When you conduct experiments, there's always a need for someone to lead and provide insightful thinking. However, if you fail to create secondary leadership and a replicable or scalable model, it becomes a failure. As I reflect on my third year at PMU CARES, I must envision a scenario where I, Vijay Borges, do not exist; "Will this model reach an acceptable level of efficiency autonomously?" That's what we have been striving for. It's not just about having the right team or leader. It's about ensuring the model's replicability and scalability.

At PMU, I have created R&D teams: one is Educational, and the other one is Engineering. When you are talking about robotics, hands-on experiences, and maker spaces, what is required is a model and an understanding of appropriate teaching and learning materials that are adaptive to hardware and software tools. Many commercial entities may have their promotional interests. So, to drive the government's interests, the need is to minus the commercial interest and keep the primary stakeholders' (students') interest as the highest priority. This can be done only by developing the tools ourselves. So, when PMU signs the MoU, with other entities, the emphasis is to develop the IP together. When we speak to system integrators, we insist on developing the firmware together. By doing this, PMU develops in-house expertise and becomes efficient in being adaptable to create a teaching learning framework that works efficiently with the hardware and software tools.

For experiential learning, the need is to be clear about what is going to be taught, the tools required and how the tools would be adapted five years down the line. Can these resources be reused? Can they be efficiently used? We engage with industry partners on these terms as envisioned by the PMU.

Dr Chintan Vaishnav: Initially, three factors led to a slightly larger concentration of schools in some regions. Of India's secondary and higher secondary schools, 4.4% have an ATL. In some regions, that number may be 5.5%. These variations exist because, first, the schools that were closer to Delhi, and second, regions where awareness and focus on education are higher, such as southern areas, obtained more schools because they actively applied for them, sometimes using third-party agencies to submit applications, which introduced some bias since allocations was based on applications. Lastly, in the frontier regions like J&K, there were fewer initial applications. However, apart from these factors, there was no predetermined ratio imposed.

Shri Himanshu Gupta (IAS): We have partnered with the Australian Council of Education Research (ACER), which serves our Project Management Unit (PMU) assisting in the design and development of assessments. In addition, various curriculum design partners have provided their expertise. An innovative aspect of our approach has been the involvement of our own teachers in devising assessment strategies. This collaborative approach has resulted in the development of a co-assessment framework, fostering stakeholder involvement and garnering positive feedback on our student assessments. We conduct weekly and fortnightly assessments, giving substantial weight to internal assessments within a semester-based system, aligning with the draft National Curriculum Framework's recommendations.

Maulika Kulkarni: What are some innovative government programs related to CS education that have yielded positive results? Could you highlight a few success stories?

Dr Vijay Borges: To run the elective curriculum - which is a post school hours activity - on advanced technology for selected motivated students, we offered the Teach for Goa Fellowship. Around 50 graduate/postgraduate engineers and MCAs join us for 2-3 years to engage in school education, primarily to assist us in delivering the curriculum. This curriculum is highly specialized, focusing specifically on mathematics, science and technology. We harness the existing talent pool from the local engineering institutes, providing them with training to supplement school education.

Our Teach for Goa fellows go to various schools for these post school hour sessions. We implemented a concept called the "Hub and Spoke" model. Across the 12 talukas, we assigned one school as the "hub" or lead school, while the seven schools serve as "spoke" schools. How does this work? The students from the spoke schools along with hub school students convene for a weekly two-hour session. In each session, there are a maximum of 20 students.

A system is allocated to a pair of students. In each hub school two sessions are conducted every day, with a total of 12 sessions in a week. We have 115 hub schools catering to over 8,000 students. We observed that students who came from underprivileged backgrounds worked together with students of privileged backgrounds, giving them a sense of, "Yeh mujh se bi hota hai" ("Even I can do this"/ "Now I know how to do things I had never done before"). It was truly remarkable to witness this change in confidence fostered through the peer learning mechanism.

Dr Chintan Vaishnav: In Atal Innovation Mission (AIM), quantitatively, we think the return on every rupee invested is about five and a half rupees as a whole. If you compute the social cost of capital, then it may be about 17 rupees for a single rupee invested. The way we computed this, which is getting published, is a two-part story. One part is incubators, where there are ideas. The incubators have the idea. So, we have invested a total of 325 crores directly into startups, plus some amount on incubators. These startups have raised about 1,350 crores in the market. They have diluted 20% of their stakes on average. This means that these startups have a valuation of about 6,700 crores. That is one form of return. These incubators have raised about 60 crores in matching funds. That is infrastructure valuation.

Through that ATLs, we have sensitized around 75 lakh students. We have computed that had such a person sought a similar level of sensitization privately, they would have spent 1,000 rupees, very conservatively. So that is about 750 crores. So, we come to 8,500-8,700 crores. We have spent 1,511 crores by last year on Atal Innovation Mission. We have had a return of 8,700 crores. So that is five times. It is interesting that the incubators have high returns but less volume, right? These 3,000 startups employ 14,500 people. They pay them maybe 30,000 rupees a month on average, so that is about 450 crores. So ATL's returns are small, but the impact is larger. That is just quantitative.

Maulika Kulkarni: How does the National Education Policy (NEP) support and enhance computer science and STEM education in the country? Please highlight any challenges or opportunities you foresee.

Dr Vijay Borges: This question is both important and interesting! We are impacting 65,000 students and not everyone is interested in coding. There could be some students interested in advanced technological knowledge. There are different kinds of learning styles. There is some innateness and then there is some that is acquired.

We develop our own tools — both, the software and the hardware tools. For a small state like us, we need to specialize in nurturing human resources. That's what we did. We came up with something called an elective curriculum. The elective curriculum is where we talk about STEM (science, technology, engineering and math). Here we prioritize higher order of thinking, based on computational thinking, design thinking and mathematical thinking. This has also been emphasized in NEP 2020.

We need to build a symbiotic relationship with talent. Otherwise, the talent will go outside Goa. This is a concern we need to address for the future, looking ahead about ten years from now. Higher education often encounters a problem when a child reaches the age of 20 and it is realized that the talent is not good or not at the desired level. By that time, it's challenging to make significant improvements to the human resource to be adaptive to the required talent pool.

Dr Chintan Vaishnav: We are getting requests for ATLs from far off places. So clearly awareness is growing. Now we do hear from some places where people have complained or demanded in their school, "I have never been given the opportunity to be an ATL teacher." That is an interesting demand! So, I think it is growing. Maybe that is an indication of being mainstream. It must come from the people, right? Otherwise, everyone is very good at making large claims.

Himanshu Gupta (IAS): I think we are in perfect alignment with what NEP 2020 says. NEP talks about activity-based learning, having career opportunities in line with the skills that are right now required in the industry. This is what we are doing. We are providing them with those skills. Then, our assessments are not like a normal Board's assessment, where you mug up theory and then you just write it in the exam. We are having a mix of both.

Suppose a child takes music as a core subject. Then 70% of her assessment will be through practical, and she will be performing, and there will be an external assessor who will be assessing. They will be given an opportunity to choose which instrument they want to play and which genre they want, whether it is Hindustani Classical, or Western. Accordingly, their assessment will be done. In different subjects, we have kept that component, and we are giving them grades. We have introduced a credit system. This is what NEP talks about. So, we are giving them credits and a grade system. That way, we are totally in line with NEP 2020.

Maulika Kulkarni: In your opinion, what role does collaboration between the government, the private sector, and educational institutions such as schools play in advancing CS education in the country?

Dr Vijay Borges: Despite the worldwide chip shortage, conflicts and challenges starting in 2021, we have successfully upgraded computer laboratories in all 460 schools, providing over 4,600 systems with all the necessary tools. This achievement represents a win; the people witnessed what a committed government can achieve. Merely setting up systems in the lab without any means of communication, such as internet connectivity, is set for failure. To address this, we adopted an innovative scheme called "Wired Internet in Schools." The government providing a single vendor to provide internet services could present a single point of failure. To overcome this, we proposed involving around 100 vendors to provide internet services through a rental model. This empowers institutions in an almost revolutionary manner. It allowed them to choose the best services. This also promoted trust and collaboration among stakeholders.

Initiatives like these are collaborative, win-win for all, and come with an inherent distributed functionality; thus, boosting any kind of learning permeability. Another feature of this scheme is the provision of engaging with Teach for Goa Volunteers and

Mentors. These volunteers and mentors are industry experts who have been associating with the scheme to provide their expertise in various domains to take these initiatives forward.

Dr Chintan Vaishnav: It would have to be state-led. It may remain a central sector, like it is right now. The answer is not there yet. What is clear is that you cannot do it from the centre, because the numbers are large. And ultimately, schools are answerable to the machinery at the state level.

We try to link it to the states even as a part of their teacher training programs. We have said that there will be involvement by the states even in selection. We have allowed schools to apply as clusters and let the states shortlist them first. They are involved in every step, so that would ultimately be the model here.

Shri Himanshu Gupta (IAS): Boston Consulting Group (BCG) was given the main aim of identifying good partners in different fields for our PMU. And on the DBSE front, we had the Australian Council of Education Research. So, BCG played a very important role in identifying the correct people.

Then we reached out to them and then centrally managed all the things. And then we have a good team in DBSE, headed by the CEO, Mr. K. S. Upadhyay. We have built a team that is passionate and dedicated towards changing the landscape of education in this country.

Dr Vijay Borges currently is the Project Director, Project Management Unit, Coding and Robotics Education in Schools (CARES) Scheme, Directorate of Technical Education, Government of Goa (GoG). Previously he has held the position as Joint Managing Director - Info Tech Corporation of Goa. He was also Officer on Special Duty (OSD) to the Information Technology Minister, GoG. He has also served as a professor at Goa College of Engineering and has more than 25 years of experience in the IT Industry, Academia and Research.

Dr Chintan Vaishnav currently serves as Mission Director for Atal Innovation Mission (AIM), which is a flagship initiative of Government of India under the auspices of NITI Aayog. Chintan is on leave from Massachusetts Institute of Technology (MIT) for his present assignment. He is an engineer trained to design and build large-scale systems that possess both human as well as technological complexities. As a teacher, innovator and entrepreneur, he has split his time between teaching and research at MIT and living and working with rural communities in India to build solutions that can overcome constraints fundamental to improving human conditions.

Shri Himanshu Gupta (IAS) is the Director Education, Government of NCT of Delhi and the Chairperson of the SoSE society. He is an IAS Officer of the 2012 batch. He has been spearheading all the education projects and initiatives under the Directorate of Education ranging from enhancing teaching-learning processes in schools to ensuring quality infrastructure. Shri Gupta did his Mechanical Engineering from IIT Delhi. In his earlier roles as an administrator, he has been the Deputy Commissioner of Longding District, Arunachal Pradesh where he successfully resolved the network issues in the area while consistently dealing with insurgency.

Maulika Kulkarni is a Partnerships Manager with Pi Jam Foundation, where she works to align government agencies and partners with the organization's vision to democratize computer science education in India.
She started her journey in education as a language teacher, which led her to a TFI fellowship. Seeking a broader social impact, she has also pursued an MSW degree from TISS.

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Recomposing computational thinking in schools, one teacher at a time

A conversation with Sonia Garcha

Sonia Garcha is a community development practitioner, who is also associated with CSpathshala, an Association for Computing Machinery India (ACM India) education initiative, where she contributes to strategy development and implementation. CSpathshala works to bring modern computing curriculum to Indian schools. ACM is a nonprofit organization and the world's largest Computing Society. Its education initiatives produce and update curricular recommendations.

Samuhik Pahal (SP): How did CSpathshala start working in the Computational Thinking (CT) space in India? What were the initial challenges?

Sonia Garcha (SG): Today digital skills, problem solving, critical thinking and analysis, technology design and programming, and reasoning and ideation have become relevant for all of us to be successful in the digital economy. Computational Thinking (CT) is a foundational skill for all. It is a practice that is central to all sciences, not just computer science. World over, K-12 computing education is moving away from digital literacy to a computational thinking curriculum.

Introducing CT curriculum for schools in India has had several challenges. Apart from the cultural and regional diversity, India has over 1.6 million schools offering K-12 education to 300 million students. India has 44 education Boards! The twin problems of filling up the large skills gap in the area of computing and the diversity of the population that needs to be trained quickly make this into a grand challenge.

Association for Computing Machinery (ACM), India, started CSpathshala, a national school education initiative, in 2016, to develop a computing curriculum for K-12. CSpathshala has evolved the curriculum and contents by piloting these across schools around the country. Computational Thinking (CT) is not just programming and use of technology. Our goal is that students develop a systematic approach to problem solving, and break down the solution into small steps that a computer can execute.

The curriculum committee comprising of academia and experts from the industry developed a high-level curriculum of what should computational thinking curriculum be in K12 education. A detailed syllabus document in different thematic areas, with an implementation plan and teaching aids, was prepared with the help of volunteers.

While CT created excitement, there was no clarity among the community of educators and teachers about what CT is and whether promoting CT in schools is necessary. We conducted awareness workshops for the decision makers, such as government officials, trustees, and principals to motivate them to teach computing as a science through an enhanced understanding on why CT should be taught in schools and how CT is different from ICT. Following this, we conducted special teacher training workshops to train teachers on the fundamentals of CS, and to take them through our new computing curriculum. Building a community of practice enabled the teachers in sharing challenges and innovative practices.

Then the question became, where do we fit it in the school curriculum?

What was being taught in schools in ICT or computer classes? the focus was on digital literacy, teaching them MS-Word, PowerPoint, etc. Students were also being taught acronyms and history of computers and coding. What they ended up doing was just teaching a plethora of programming languages, and students learnt some syntax. There was a gap in the existing curriculum.

The principles of computational thinking, viz. decomposition, pattern recognition and generalization, algorithms and programming are covered in the CSpathshala curriculum. An algorithm is something that everyone needs to understand. Ask someone for directions to reach their home and you realize how people are unable to give precise instructions.

The students first learn following instructions with activities like “Robot Game,” and then move on to the process of devising algorithms with activities like “Guess my Birthdate.” In our curriculum there is a defined progression of the syllabus across the thematic areas based on the existing school curriculum.

Samuhik Pahal: So, this syllabus was created and then teachers were trained. However, how does this curriculum get transacted in the classrooms?

Sonia Garcha: In the first year, we implemented a small pilot in Pune with 15 schools. The teachers training and the teaching aids for classes 1 to 8 included a slide deck, lesson plans and student worksheets. These could be used by teachers in the classrooms. They were provided at no cost to the schools.

We also undertook regular school visits and conducted feedback workshops from teachers to document what was working, and what needed to be changed. At the end of the first year, we grew from 15 schools to 100 across four (4) states. Since the school curriculum is too crowded to add new subject material, the time already allotted for ICT/Computer in classes 1 to 8 were productively restructured to include teaching computational thinking.

During the teachers’ feedback sessions, teachers shared that CT activities have also helped reinforce concepts in math. Mathematical thinking and computational thinking are closely related. Math involves

CSpathshala

executing algorithms — long division, computing GCD and LCM. Schools adopted multiple routes for implementation of CT. These included integration with computer science, replace existing ICT curriculum, integration with math or being taught as an extra-curricular subject. Tamil Nadu state education department has included CT as part of the mathematics curriculum since 2018 that reaches 30,000 schools.

Moving to rural government schools, the primary schools have an all-subject teacher, who teaches all the subjects and lack resources. To make computing equitable, CSpathshala has adopted the unplugged approach of teaching computing without computers.

To give you an example, one of the very popular unplugged activities is solving Sudoku. Instead of starting with a complex 9x9 Sudoku, the students start with a simple 4x4 Sudoku moving on to 6x6, and then to a 9x9. The objective here is not to teach students to solve Sudoku, but to teach them decomposition, so that they learn how to break more complex problems into smaller ones, devise algorithms and use generalization to extend the solution to solve more complex problems. Teachers have replaced numbers with shapes if children have difficulty solving 4x4 Sudokus.

Another daily life example is looking for patterns. In classes one and two, students start looking at rangolis - understanding repeating patterns, visualizing patterns and drawing rangolis. In higher classes, students study symmetry as a pattern. They use repetitive addition for multiplication, GCD as examples of patterns, which is a part of the math curriculum.

Samuhik Pahal: CSpathshala has also been able to quickly scale up its work. What has been the contours of this journey? What are the challenges that the organization has faced in this process?

Sonia Garcha: Since 2018, we started working with Andhra Pradesh Social Welfare Residential Educational Institutions Society's (APSWREIS) tribal welfare and ashram schools. There were 200,000 students from 427 schools across 13 districts learning computational thinking. To achieve scale and develop a sustainable model, we shifted to training the master trainers, who in turn trained the teachers and provided handholding support for CT implementation.

One of the most important learnings was the adaption to local contexts by the teachers. A related question is - how you share your classroom activities and innovative approaches that you have implemented. Teachers shared photographs and videos of CT activities that they had implemented on WhatsApp groups. Volunteers helped teachers publish blogposts on the CSpathshala website.

The CTiS (Computational Thinking in Schools) conference is an annual event organized by ACM India (Association for Computing Machinery India) and the CSpathshala community. It aims to bring together teachers, educators and researchers to discuss issues of curriculum, pedagogy, policy and implementation, related to bringing computational thinking to schools.

CTiS-2019, the first conference, had teacher presentations on challenges faced and innovative approaches used to implement CT activities in the classroom. For the first three editions of CTiS, we had submissions from computer teachers and a few math teachers too.

CSpathshala's work at the policy level enabled the inclusion of CT in National Education Policy (NEP) 2020: Section 4.25 of NEP 2020 says:

> "It is recognized that mathematics and mathematical thinking will be very important for India's future and India's leadership role in the

> numerous upcoming fields and professions that will involve artificial intelligence, machine learning, and data science, etc."
>
> Thus, mathematics and computational thinking will be given increased emphasis throughout the school years, starting with the foundational stage, through a variety of innovative methods, including the regular use of puzzles and games that make mathematical thinking more enjoyable and engaging. Activities involving coding will be introduced in Middle Stage."

We also received feedback from science teachers that the skills in critical thinking and logical reasoning being developed through our CS curriculum were helping students better grapple with concepts in science. Our children are observing their surroundings, identifying patterns, and are curious to explore how things work. After 2021, we have seen a sea change. Along with computer teachers, language, science, math and social studies teachers, are now exploring the integration of computational thinking as part of the school curriculum.

Samuhik Pahal: How do you engage with the governmental system to ensure that the CSpathshala curriculum gets transacted in government schools?

Sonia Garcha: We have been closely working with state governments. Specifically, we have engaged with Andhra Pradesh Social Welfare Residential Educational Institutions Society, Zilla Parishad Schools in Maharashtra, Goa, Gujarat and Tamil Nadu in implementing CT. Teaching programming is an important area of work. However, it will not be possible to teach programming across all schools unless we are able to find a scalable model to provide affordable computing devices, supplemented with access to other amenities such as power supply and basic infrastructure.

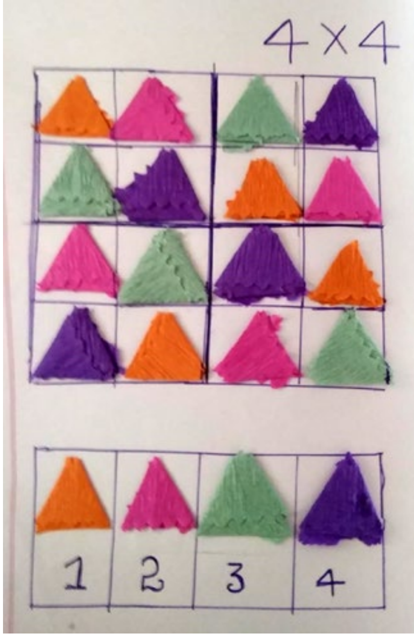
To address these challenges, and make computing equitable, CSpathshala has adopted the unplugged approach of teaching computing without computers. This has been piloted with 600,000 students in 1,500 schools across 11 states in four (4) languages. Two thirds of these are rural government schools, demonstrating that computational thinking is for all!

Our whole ideology is about mainstreaming the CT curriculum. In National Education Policy 2020, and in many countries across the world, Computational Thinking (CT) has been identified as one of the essential subjects to be taught and a critical skill to be developed in children during the school years. It advances the notion that the mathematics and the science behind computer science, go far beyond the simple ability to use computers, and can be taught and discussed in schools even without the use of computers.

With the inclusion of CT in formal curricula of mainstream subjects like math, science and social studies, there will be dedicated time for CT in the academic calendar, and the provision for training teachers. NEP 2020 also mentions inclusion. With this, the students in rural, semi-urban and government schools, who were typically excluded, will now benefit with opportunities to learn computing.

However, there is a flipside to this as well. Computational thinking has now become the new buzzword. In urban schools, the inclusion in NEP can lead simply to new subjects like Artificial Intelligence (AI) and Machine Learning (ML) introduced at school level, entirely missing the conceptual basis of CT. CSpathshala's position on CT is that it should be taught at par with mathematics and sciences and not be reduced to programming.

Samuhik Pahal: You have mentioned teachers' training and engagement as a critical part of your approach. Could you please elaborate a little on this?



CSpathshala

Sonia Garcha: We believe that teachers' training is an important component for the successful implementation of CT by conducting interactive sessions through activities and imparting CT knowledge. CSpathshala has played an important role in building teachers' capacities to train students to develop the ability to solve problems and explore multiple solutions toward solving problems.

While conducting teachers training, we don't initially mention the four pillars of CT. To help teachers overcome the fear of CT, we take examples from daily life. For example, this may include an initial question on how to make a cup of tea. This then leads to a discussion on the various ways of making tea and the different steps involved. It then morphs into deliberations on giving precise instructions and devising algorithms. During the training sessions, the focus is on pedagogy and CT skills. We demonstrate how the activity should be taught in the classroom and then ask the teachers to conduct it during the training. This helps build teachers' confidence to conduct the activities in the classrooms.

I really take pride in the CTiS conference, which is a platform to bring teachers together. This year, we had more than 200 submissions for the conference. Forty-four submissions from these were selected for the final national conference, with more than 200 participants, and around 2,000 people participating online. We have also organized two regional conferences in Maharashtra and Andhra Pradesh, to provide a larger number of teachers opportunities to present and showcase their work.

Samuhik Pahal: What are the ways in which your organization has tried to address concerns related to inclusion in CT?

Sonia Garcha: CT and inclusion is not just about teaching the CT unplugged curriculum, but also going beyond by providing an opportunity to the unreached rural and government schools. Vision Empower (VE), who work on STEM education for the visually challenged, adapted CT content to teach visually impaired children. Ongoing conversations with the VE team have been an important part of our learnings in the CT and inclusion space.

During CTiS2022, we also organized the Tactile Accessible Computational Thinking (TACT) Grand Challenge. The pedagogy of Computational Thinking has been more visual than tactile, thereby leading to lack of inclusion in classrooms. The aspiration of this challenge was to create a novel approach to CT, which can be equally accessible for learners with speech, hearing or visual impairment or those without any impairments. We received submissions from academia and teachers from India and overseas, and the selected activities were showcased at CTiS-2022.

In CTiS-2023, we had a special CT and inclusion track for teachers and educators working with students with special needs. CTiS-2023 conference also had submissions in five other languages apart from English – in Gujarati, Telugu, Tamil, Hindi and Marathi. The goal was to provide our rural and government schoolteachers opportunities to present.

Samuhik Pahal: If you could please reflect a little on the challenges of working at scale when one is a voluntary organization?

Sonia Garcha: For us, our volunteer group who joined us in 2016 has worked well. It continues to contribute to the initiative. We have had a large number of volunteers across five (5) continents during content creation.

CSpathshala also organizes the Bebras India Challenge, which is conducted free in seven languages to provide opportunities to the unreached rural and government school students. Since 2018, over 500,000 students in the age group of 8-18 years have participated in Bebras India Challenge. Bebras is an international Computational Thinking Challenge for students organized in over 74 countries. It is designed to get students across the world excited about computing. Our volunteers help in translations. They also reach out to schools to popularize the challenge.

During the CTiS conference, volunteers are actively involved in the various committees. They play an important role of reviewing the abstracts and mentoring the teachers. It is also a gratifying experience for our volunteers who have created the content to see the impact shared by the teachers during the presentations. I am happy to share that the CSpathshala family – our volunteers – are one of our biggest strengths. Without them this impact would not have been possible.

CSpathshala's efforts are showing a positive impact both at the school and policy levels. Through our work, we have been able to show that it is possible to convey the essential ideas of computing to all school students without drastically disrupting the existing system. All we need is some open mindedness and vision among schoolteachers and administrators. Computational Thinking is fundamental for all, not just for computer scientists!

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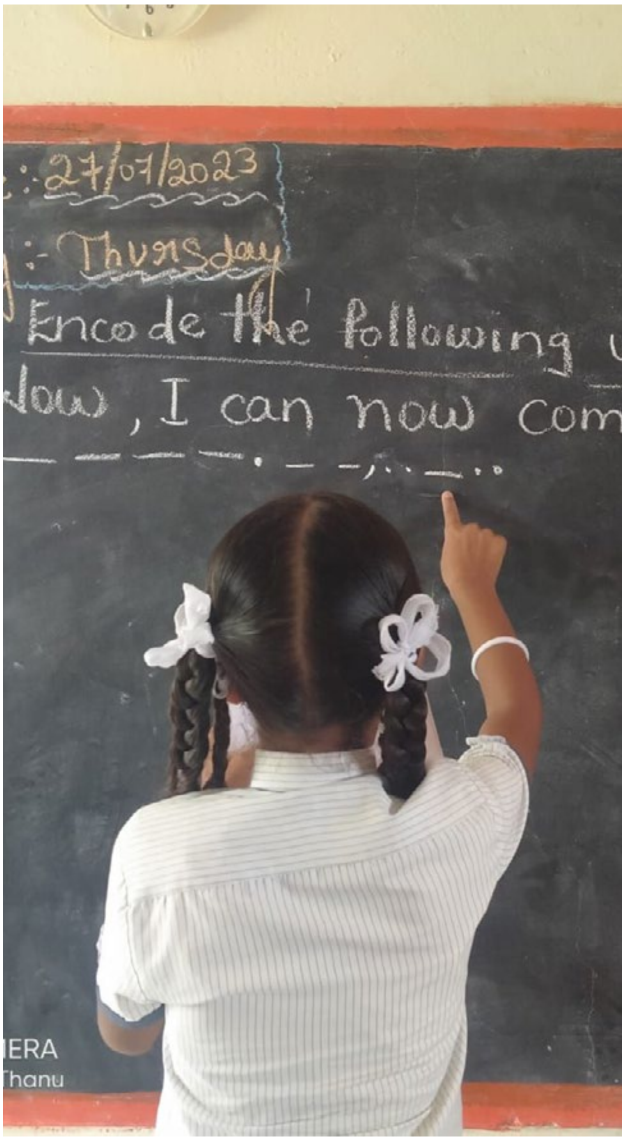

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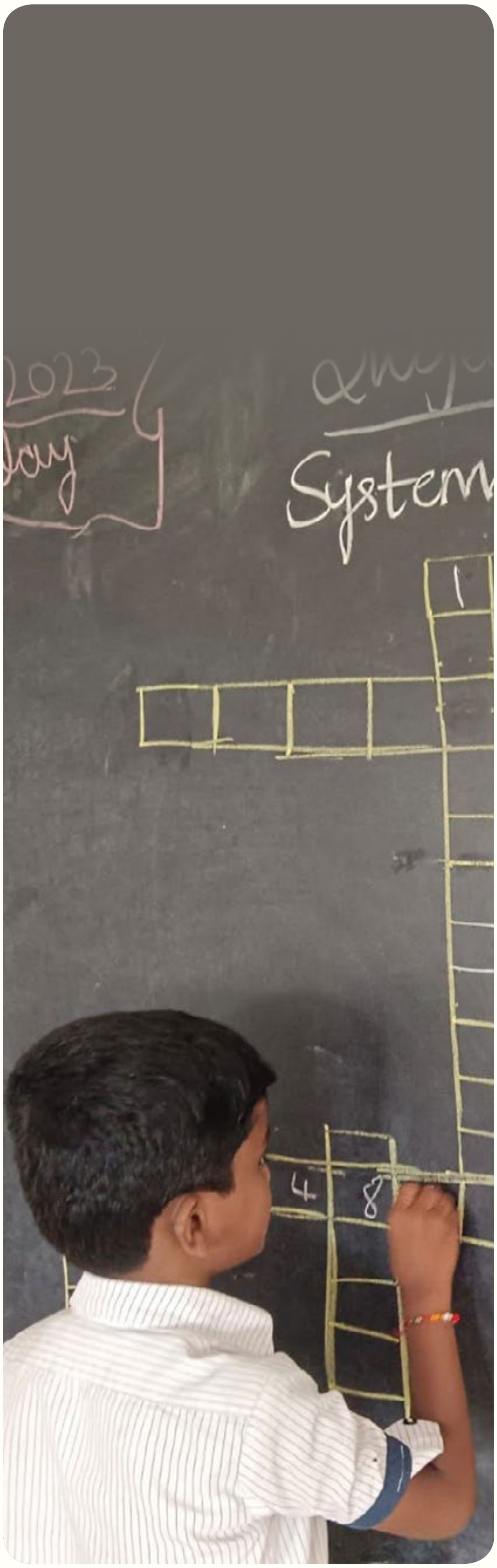
Teaching and learning resources for computing education

Nikhil Agrawal and Aastha Maggu

We have curated a collection of resources (shared in the table below) dsesigned for self-paced learning, teaching assistance, community engagement, and platform access. These resources cater to children, parents and educators interested in hands-on learning experiences in various aspects of computer science (CS) education, including coding and digital literacy.

Resource	Creator/ Curator	Type of resource	Skills	Target audience
Code Mita	Pi Jam Foundation	Interactive CS courses, contextualized training modules for teachers and curricular resources hosted on a mobile application	Problem solving, computational thinking and creativity	Learners of any age
Let's code	Pi Jam Foundation	Culturally contextualized CS course	Digital citizenship, creativity and computational thinking	Learners of any age
Scratch	Scratch Foundation	Visual, block-based programming for creating interactive animations, games and stories	Problem solving, computational thinking, creativity	Learners of any age
CSpathshala	CSpathshala	CS curriculum, syllabus, and curricular resources	Problem solving	K-12
Hour of Code	Code.org	Educational coding: one-hour tutorials on computer programming and computer science	Problem-solving, logic, creativity and digital literacy	Learners of any age
Computer science courses	Code.org	Curricular resources and coding tutorials	Problem-solving, logic, creativity and digital literacy	Learners of any age
Computing curriculum	Raspberry Pi Foundation	CS curriculum, syllabus and curricular resources	Coding, programming skills, problem solving, creativity, collaboration and communication	Learners aged 5-16 years
Computing course	Khan Academy	Online computing education platform	Computational thinking	Learners of any age
Google Exploring Computational Thinking	Google	Computational thinking resources repository	Computational thinking	Learners of any age



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