REIMAGINING COMPUTER SCIENCE REQUIRES INTEGRATION

How to integrate foundational and advanced computer science content at the high-school level

Our world is powered by computing, and recent advances in AI are only accelerating our collective reliance on it. The need for early, universal computer science (CS) education is becoming ever more important, as all students need quality CS education if they are to become informed citizens and confident creators.

Yet most students still do not learn CS. According to the 2024 State of CS Report (**helloworld.cc/state-of-cs-2024**), 60 percent of public high schools in the US offer at least one CS course, but just 6.4 percent of high-school students took one last year (if all students took one CS course during high school, we would expect to see enrolment of around 25 percent). There are also persistent disparities in who takes CS courses.

I have always been a proponent of stand-alone CS instruction to promote quality instruction and equitable implementation. To reach all students, though, it is necessary to integrate computer science into other subject areas. Adding another subject to an already overflowing curriculum is daunting, and the number of existing instructional requirements gives little wiggle room, especially for students who require more support (for example, multilingual learners who also take an English language development course, or students who need to retake a course). Many schools cannot add CS courses without displacing other important courses in a wicked zero-sum game. This is especially true at smaller schools, where there is typically a narrower course menu; for them, integration may be the only option.

When done thoughtfully, integrated instruction can be meaningful. De-siloed instruction enables relevance, and application that is more similar to what we want students to be able to do in the real world. Ideally, schools would not choose one approach, but offer both. This enables students to develop a strong foundation akin to that in other disciplines, while also allowing them to apply and extend this foundation in relevant and engaging ways.

Integration in high school

While much existing work on integrating CS focuses on elementary grades, it is just as important in high school. This can take the form of an integrated course such as Bootstrap:Algebra (**helloworld.cc/bootstrap-algebra**), which integrates CS into algebra courses, or SFUSD's Creative Computing course (**helloworld.cc/creative-computing**), which integrates CS into an introductory digital arts course. Reimagining CS Pathways defined several compelling X+CS pathways too (**helloworld.cc/xcs-pathways**), for example, computational journalism.

Foundational CS can also be meaningfully integrated into existing coursework in smaller ways, such as within a single lesson or unit. **Figure 1** shares some examples of how CS can enhance instruction in other subject areas.

> ### REIMAGINING CS
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> Over the past two years, the Computer Science Teacher's Association (CSTA), the Institute for Advancing Computing Education (IACE), and our partners have sought to reimagine CS education. The Reimagining CS Pathways (**reimaginingcs.org**) project resulted in a community definition of foundational computer science content. It differs in a few notable ways from current curricula, including a greater focus on social impacts and ethics, algorithms and computational thinking, data and AI, emerging technologies, and the need to connect CS learning to careers. This article highlights integration guidance from the Reimagining CS Pathways report.

Beyond the foundation

When all students develop a strong foundation in CS, teachers can leverage and extend their CS knowledge and skills beyond the foundation level and into other non-CS courses. Integration is thus helpful not only in the teaching of the foundation, but also in the teaching of advanced content. Here are some examples illustrating how more advanced AI content can be integrated into other courses, after students have learnt foundational CS:

Science: students use sensors to gather data about a chemical process and analyse it using an AI library.

- **Mississippi Career-Readiness Standards for Science (helloworld.cc/**

SUBJECT	SUBJECT CONCEPTS	CS CONCEPTS	SOURCE
English language arts: using a text file of *Romeo and Juliet*, students record counts for each character's dialogue and then visualise that data. Using the visualisation, students look for patterns in the data and then use the patterns to confirm what is known about the play and generate new questions about the text. Students also assess word frequency per scene to look for patterns in the text.	Close reading for meaning and tone	Types of data, data cleaning, data analysis, and visualisation	Integrated Computational Thinking (**helloworld.cc/integrated-CT**)
Mathematics: students create flags using a combination of maths and CS concepts. First, students sketch the image on graph paper, then they experiment with predefined functions to decompose elements of national flags and compose additional flags.	Ratios, coordinates, scaling	Functions, decomposition, image manipulation, comments	Bootstrap:Algebra (**helloworld.cc/making-flags**)
Science: students develop and experiment with computational models to explore the behaviour of a forest fire and its impact on the forest ecosystem.	Ecosystems, evolution, patterns and systems, using models	Clearing, analysing, and visualising data; troubleshooting and debugging	CT-STEM (**helloworld.cc/ct-stem**)
Social studies: students explore patterns in population change across countries and time spans. They create multiple data visualisations by using a specialised tool to adjust parameters to generate the appropriate visualisation, which can then be analysed.	Population growth patterns, data literacy	Function parameters, data visualisation	Data Visualization for Learning (**helloworld.cc/teaspoon-programming**)
Fine arts: students create a song by using predefined functions with the appropriate parameters, as they practise using music concepts and terminology.	Elements of a song (tempo, measures, sections)	Functions, parameters	EarSketch (**helloworld.cc/earsketch-tutorials**)

Figure 1 How CS can enhance instruction in other subjects

mississippi-science): 'Students will use mathematical and computational analysis to evaluate problems.'

- **AI concepts:** sensors, perception, and classification; using data: collection, cleaning, data types, validity, bias.

Social studies: students develop a plan of action related to the environmental costs of developing LLMs.

- **New York Learning Standards for Social Studies (helloworld.cc/ny-social-studies):** 'Prepare a plan of action that defines an issue or problem, suggests alternative solutions or courses of action, evaluates the consequences for each alternative solution or course of action, prioritises the solutions based on established criteria, and proposes an action plan to address the issue or to resolve the problem.'
- **AI content:** using AI tools to solve problems; ethical frameworks, philosophy, psychology, bias.

Mathematics: students analyse the output of unsupervised learning models that categorise data.

- **Texas Mathematics Essential Knowledge and Skills (helloworld.cc/texas-math):** 'Students will extend their knowledge of data analysis and numeric and algebraic methods.'
- **AI content:** using data sets, regression, probabilistic thinking; representation and reasoning, KNN, vectors.

Fine arts: students explore similarities and differences between how AI models and artists make use of the intellectual property of others, as well as the ethical and legal ramifications of such use.

- **Nevada Visual Arts Standards (helloworld.cc/nevada-visual-arts):** 'Demonstrate awareness of ethical implications of making and distributing creative work.'
- **AI content:** biases in data collection, analysis, and reporting; AI programming.

English language arts: students write prompts using techniques such as few-shot prompting.

- **Illinois English Language Arts Learning Standards (helloworld.cc/illinois-english-language-arts):** 'Produce clear and coherent writing in which the development, organisation, and style are appropriate to task, purpose, and audience.'
- **AI content:** natural interaction, semantics, chatbots; prompt engineering.

When all students are prepared for a world powered by computing, they will be empowered to utilise foundational CS knowledge and skills in their personal lives, communities, and careers. The more we can teach the meaningful integration of CS, the better students will be prepared to continue to do this on their own. (HW)

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