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Computing Everywhere, for Everyone, at Any Level

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OVER THE PAST few decades, computing has emerged as a transformative discipline, significantly reshaping the world. Virtually all knowledge areas now use computing to enhance their applicability, and even everyday activities often require some computing knowledge. Recent advancements in artificial intelligence (AI) have highlighted the profound impact computing has on our lives to everyone. Therefore, it is desirable that students of all levels have age-appropriate familiarity with computing.[5,6]

Several international efforts, including frameworks and reports, have emerged to address the development of early computational skills. Some of the most relevant are the "K–12 Computer Science Framework,"[3] which establishes guidelines for computer science education for grade-school students; the "Informatics Reference Framework for Schools,"[1] which offers a structured approach to introducing informatics and computational concepts in educational settings; and the "Brazilian Computing Standards for School,"[4] which defines essential competencies and knowledge for computing education in Brazilian schools. Frameworks such as these are invaluable resources, guiding educational institutions in integrating computing concepts into their curriculum and empowering students to develop essential computational skills throughout their academic journey.

The initial step in defining any computing standard is to provide a clear and accessible definition of what computing is [allowing] anyone to comprehend not only the essence of computing but also its relevance in the world.

These frameworks have evolved significantly due to the challenge of precisely defining which computing abilities should be introduced at the school level. This complexity arises because computing is still a relatively new area and must be better understood by many. We contend the initial step in defining any computing standard is to provide a clear and accessible definition of what computing is. Such a definition should enable anyone to comprehend not only the essence of computing but also its relevance in the world, particularly in shaping the citizens of the 21st century and beyond. Without this understanding, it becomes challenging for teachers, professors, or legislators to endorse any proposal related to computing education.

To develop a framework for explaining computing, the Brazilian Computer Society established a task force comprising collaborators from various computing fields with extensive

experience teaching computer science. The goal was to create a framework for explaining computing to everyone. To achieve this goal, the task force had to convince several stakeholders, starting with members of the Brazilian Science Academy, to present the main ideas during public hearings organized by the Brazilian Education Council, and meetings with members of the Ministry of Education. The two main requirements set to build the framework were: It should encompass all concepts and abilities essential in computing in a clear, simple, and understandable way; and it had to be adapted to the complexity of the Brazilian educational environment. By analyzing different existing standards and considering the task force expertise, a mind map was created, and three main clusters appeared:

1. **Computational Thinking**: This pillar embodies the art of comprehending, analyzing, and devising solutions to diverse problems by creating and adapting algorithms. Algorithms describe processes and facilitate the systematic organization of data while applying fundamental computing principles.
2. **Digital World**: The Digital World pillar entails versatile skills to comprehend and manage digital, physical, and virtual computing artifacts. It also encompasses expertise in information representation, enabling secure data storage and transmission.
3. **Digital Culture**: This pillar emphasizes digital literacy and the conscious and ethical use of information and computer technologies. It empowers individuals to propose innovative solutions and fosters cultural expressions while considering the broader impact on society.

The document generated by the Brazilian Computer Society served as the foundation for a working group organized by the Brazilian Education Council to build the Brazilian Computing Standards for School, which was approved in 2022 and mandates the inclusion of computing science in all Brazilian schools from kindergarten to high school. The accompanying figure shows a summary of the Brazilian Education System. We believe the Brazilian framework is comparable to other international initiatives; the main difference lies in the focus on simplicity and the foundations of computing science, making this general framework suitable for use not only in South America but also in other countries.

This was a massive step in Brazilian education because practically no computing-science skills were included previously in the Basic Education Standard. As a result, the development of computing-science competencies was not offered in most public schools.

By providing insights into the significance of computing education and promoting cross-disciplinary collaboration, we strive to equip educators with the tools to effectively integrate computing concepts into their teaching methodologies, empowering students for success in a digitally driven world.

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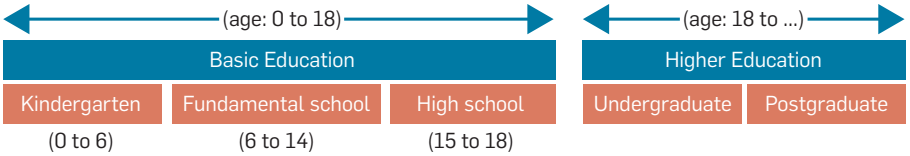
The Brazilian standard emphasizes the foundations of computing science, since it is essential to understand and adapt to new digital technologies. The set of skills that should be developed at different levels of basic education are listed here.

Fundamental School CS Competencies:

1. Understand computing as an area of knowledge that contributes to explaining the world and be an active and conscious transformation agent capable of critically analyzing their own social, environmental, cultural, economic, scientific, technological, legal, and ethical impacts.
2. Recognize the impact of computational artifacts and respective challenges for individuals in society considering different aspects, such as socio-environmental, cultural, scientific, political, and economic.
3. Express and share information, ideas, feelings, and computational solutions using different computing languages and technologies in a creative, critical, meaningful, reflective, and ethical way.
4. Apply the principles and techniques of computing and its technologies to identify problems and create computational solutions, preferably in a cooperative way, and use computing to underlie discoveries in different areas of knowledge.
5. Evaluate the solutions and processes involved in the computational solution of problems from different areas of knowledge, using computing-science knowledge to construct coherent and consistent argumentation based on facts and reliable information regarding the diversity of opinions, knowledge, identities, and cultures.
6. Develop projects to tackle problems, challenges, and opportunities that make sense in the context or interest of the student using computing science, using concepts, techniques, and computational tools to automate processes based on ethical, democratic, sustainable, and supportive principles, valuing the

Figure. Brazilian Education System overview (expected age of students).



diversity of individuals and social groups in an inclusive way.

7. Act personally and collectively with respect, autonomy, responsibility, flexibility, resilience, and determination, identifying and recognizing their rights and duties, using knowledge of computing and its technologies to make decisions regarding issues of different natures.

High School CS Competencies:

1. Understand the possibilities and limits of computing science to solve problems in terms of feasibility and efficiency, proposing and analyzing computational solutions for different domains of knowledge, and considering various aspects.

2. Critically analyze computational artifacts, identifying vulnerabilities in environments and solutions that seek to guarantee the integrity, privacy, confidentiality, and security of information.

3. Analyze situations in the contemporary world, selecting appropriate computational techniques for solving problems.

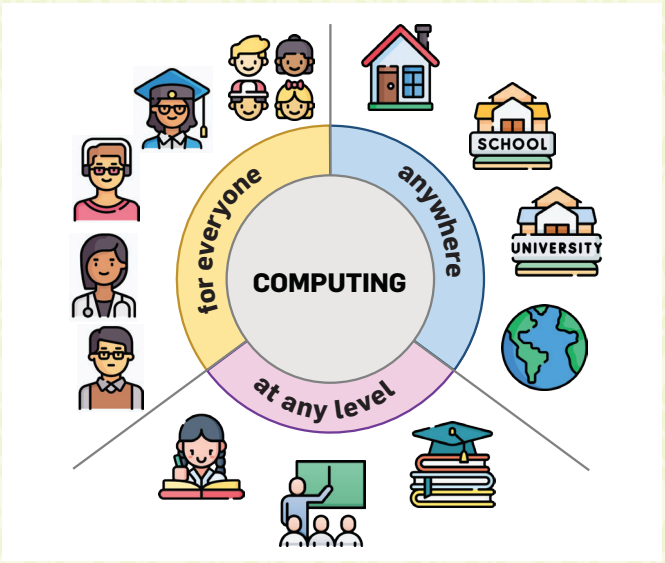
4. Build knowledge using CS techniques and technologies, creatively producing content and artifacts, and respecting ethical and legal issues.

5. Develop projects to investigate contemporary challenges, build solutions, and make ethical, democratic, and socially responsible decisions, articulating concepts, procedures, and languages from CS.

6. Express and share information, ideas, feelings, and solutions using different computational platforms, tools, languages, and technologies in a creative, critical, meaningful, reflective, and ethical way.

In a nutshell, integrating computing into educational frameworks, from kindergarten to postgraduate levels, is vital in preparing students for the complexities of our digitally driven world. The recognition of computing as a transformative discipline shows its significance in various areas of knowledge and everyday activities. In Brazil, integrating computing into basic education has become a reality, with the aforementioned competencies now being mandatory.

The evolving nature of the frameworks mentioned above reflects the challenge of defining precise computing abilities at the school level, emphasizing the need for a clear and accessible understanding of computing's essence and relevance. The Brazilian Computing in Schools Standard might be an example of a proactive approach, establishing a foundation for including computing science in all Brazilian schools. Its pillars—computational thinking, digital world, and digital culture—offer a comprehensive framework for cultivating essential skills and helping the next generations address societal challenges in an ethical and innovative way.



Cross-disciplinary collaboration and the global establishment of standards, as seen in documents such as the Computing Curricula 2020,[2] further solidify the commitment to providing a robust computing education. The proposed set of competencies for basic education, from kindergarten through high school, emphasizes critical thinking, ethical decision making, and creative problem solving, which are skills essential for navigating the dynamic landscape of the digital era.

In conclusion, by helping educators integrate computing concepts effectively, we empower students to thrive in a digitally evolving world. Thus, including computing in the Brazilian Education Standard can potentially reduce social inequities. As we advance into the future, a comprehensive computing education becomes not just a pedagogical necessity but a cornerstone in shaping informed, adaptable, and responsible global citizens for the next decades. C

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