

# Rethinking Paradigms in Computer Science Education Research for a More Inclusive and Adaptive Future

Muka Kabeya Arsene<sup>1</sup>; Oshasha Oshasha Fiston<sup>2</sup>; Musas A Musas Andre<sup>3</sup>; Kabeya Mukosayi Jospheh<sup>4</sup>; Tshielo Koka Souvient<sup>5</sup>; Kobalanga Liamba Pathy Cedrick<sup>6</sup>

<sup>1,2,3,4,5,6</sup> Commissariat General A L'energie Atomique / Centre Regional D'etudes, Nucleaires De Kinshasa (Cgea/Cren-K)

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**Abstract:** In the context of a SoTL inquiry, the rapidly changing nature of digital tools and environments may necessitate broadening the scope of computer science education research from pure technical knowledge to pursuing awareness of human-centered, inclusive, and contextual aspects. The rising complexity of digital artifacts, and their impact on society, demands a (re)configuration of educational paradigms that consider computational thinking along with ethical thinking, cognitive diversity, and social responsibility. Here, an interdisciplinary framework derived from concepts from the neuroscience of learning and critical pedagogy, educational artificial intelligence, and ethical philosophy is presented. The goal is to define a new set of learning goals that are at once technically sound and socially relevant. With a focus on adaptive learning systems and inclusive educational strategies, this approach intends to provide personalized learning experiences that are mindful of individual learners and of the larger social and cultural issues. It is through this shift in perspective that computer science education research can transcend the technical to provide a fuller account of learning in a connected world.

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## I. INTRODUCTION

Education in computing is now facing challenges that are unprecedented, coinciding with the rapid growth of digital technologies and their permeation in almost every sphere of contemporary life. Though it remains important to teach programming skills and systems design, these knowledge areas are not sufficient by themselves to prepare students for the challenges of the digital society of today. Cultivating critical thinking that allows students to interrogate and critically engage with technology systems is an imperative that shows no signs of abating. In addition, challenges related to equitable education and the diversity of cognitive approaches to learning should be tackled in a way that ensures every learner can keep up.

To this end, the aims of computer science education must shift to embrace a more comprehensive outlook. These developments involve reestablishing technological education within human-centered educational ideals, social, cultural and

ethical implications of technology within the curriculum as well as capitalizing on new knowledge in the fields of neuroscience and artificial intelligence with the use of adaptive learning environments. Such a change is required in order to bring education in line with the rapid transformation of the digital world and enable learners to develop not only technical competency but also critical insight.

## II. WHY RETHINK RESEARCH IN COMPUTER SCIENCE EDUCATION?

Historically, the study of computer science education has concentrated primarily on what it means to learn technical aspects of the subject, often with a strong cognitive orientation to efficiency and problem-solving, as well as algorithmic thinking. Although these are still core aspects, they are increasingly insufficient to represent the full range of competencies needed in today's digital societies. Some growing awareness is emerging that education has to promote a

responsible digital citizenship, which is more ethically informed and reflective, and that takes into consideration the social effects of technology.

In addition, the diverse learners in this increasingly global community require that we develop more diverse and multicultural education that considers different cultures of teaching, learning, and thinking. Some neuroscientific findings indicate that learning is greatly affected by cognitive styles, emotional involvement and personal information processing styles. For instance, Kandel et al. (2014) emphasize the need for teaching methods to be based on the operation of the human brain to improve learning. Hence, the application of neurocognitive technologies and intelligent systems in the educational domain can be seen to have the potential for defining novel, more personalized and effective modes of learning.

### III. NEW COMBINED TEACHING PRACTICES

#### ➤ *Critical and Engaged Learning*

One important aspect of reimagining CS education is critical and active learning. It is important to ensure that students have not only the skills to use technology tools, but also a deep understanding of tool limitations, the biases that are embedded in them, and the societal implications of the use of the tools. Algorithmic bias, for example, is a significant concern for applications of artificial intelligence systems and questions about fairness, transparency and accountability are raised. When students are prompted to think critically about such questions, they develop a sense of agency and are motivated to become more constructive participants in fostering a just digital society. “The algorithm’s unfettered use can exacerbate social disparities, and raise questions of fairness, transparency and accountability in its deployment — all issues that are essential components of education and critical awareness,” O’Neil (2016) stressed.

#### ➤ *Inclusion and Cognitive Justice*

Another basic point is that diversity among learners must be taken into account and what might be termed cognitive justice must be furthered. Learners have different cultural identities, cognitive capabilities, educational opportunities and challenges, and these differences need to be recognized and responded to in education systems. Multiple efforts have been made within computer science education to address underrepresentation and to ensure that all students feel represented, supported, and capable of success. Investigators for the Multiethnic Cohort (MEC): Ford et al. (2020) highlights the critical sense of urgency with which curricula and teaching practices should be developed to be inclusive of and applicable to Underrepresented Groups (URGs). Through participatory and inclusive research approaches, educators may gain insights into the unique circumstances of learners, and findings that support equitable and engaging learning outcomes.

#### ➤ *AI for Adaptive Learning*

Education is an area where the technology of artificial intelligence is being applied and can be very well suited for applications of learning adaptivity and personalization. AI-based systems can monitor students’ progress in real time, detect learning barriers, and give personalized feedback and materials. These features have potential to dramatically improve learning effectiveness and motivation as shown by Woolf (2010) in intelligent tutoring systems. The growing dependence on automation in the field of education, however, brings with it — and not without good cause — serious ethical questioning. It is important to make sure that technological systems support and enhance rather than supplant human-to-human communication and interaction with interfacing teaching or mentoring remain integral in the relational and empathetic aspects of education. Striking the right balance between innovation in technology and focus on teaching and learning as a human-centered activity is still seen as a key challenge to research in the future.

### IV. TOWARDS A NEW ETHICS AND RESEARCH METHODOLOGY

An evolution in the research methodology and ethics standards is needed to transform computer science education. Research in the future has to combine multiple perspectives and approaches, such as education, psychology, sociology, computer science among the others. This collaboration contributes to a deeper analysis of learning and the multifaceted relations between technology and society.

In line with the need for interdisciplinary research cooperation, so too must research methodology multiplicity flourish. The availability of anonymized large-scale data sets can enable us to analyze patterns of learning at a scale that has traditionally been unavailable (such as through ethnographic research that captures the lived experiences of learners and educators). Feeding into that, longitudinal studies are crucial for examining the lasting effects — and the viability — of educational innovations. Most importantly, ethics considerations need to be part of all stages of research, especially concerning issues related to data privacy, algorithmic transparency, and the biases that could be embedded within technological systems.

### V. CONCLUSION

In sum, prospective computer science education will rely on creating methods that are technically strong, socially conscious, inclusive, and personalized. Realizing this vision calls for a radical transformation of current research methodologies and a convergence toward interdisciplinary, human-centered approaches. Drawing on knowledge from neuroscience, artificial intelligence, and the social sciences, educators and scientists have the potential to create learning environments that appropriately address the complexity of

today's digital world. This shift is critical if next generation learners are to be equipped to navigate, and direct, a future where technology is an ever greater part of the centerpiece.

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