Visions of Computer Science Education: Unpacking Arguments for and Projected Impacts of CS4All Initiatives

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ABSTRACT
As momentum grows to expand K12 Computer Science (CS) education, associated public narratives often assume core questions about why CS should be taught to all students have been sufficiently answered. Having clarity around the core purposes that varied stakeholders are envisioning is critical to ensuring the coherence of CS4All initiatives. This study presents a framework examining the range of arguments for and projected impacts of CS education programs. Based on data drawn from a researcher-facilitated participatory knowledge building process involving 26 CS education stakeholders who articulated 161 arguments, we identify seven areas of impact present in arguments for universal CS education: (1) *economic and workforce development*, (2) *equity and social justice*, (3) *competencies and literacies*, (4) *citizenship and civic life*, (5) *scientific, technological and social innovation*, (6) *school improvement and reform and (7) fun, fulfillment and personal agency*. Findings show that individual arguments and visions for CS education often reference multiple impact areas. We intend for this framework to support reflection by CS education stakeholders to consider how their current initiatives index different ideologies about what CS4All projects are meant to achieve.

Categories and Subject Descriptors
• Social and professional topics~Computer science education • Social and professional topics~K-12 education

Keywords
Universal computer science education, CS4All, CS education purposes, arguments for CS education, visions of CS education.

"Educational plans and projects must have a philosophy... otherwise they are at the mercy of every intellectual breeze that happens to blow" - John Dewey, 1938.

1. INTRODUCTION
As Computer Science for All (CS4All) initiatives across the country gain momentum, questions about the underlying purposes of education that have been present in historical education debates [20] are critical to examine. Currently, many issues related to implementation, such as teacher training and capacity, curriculum, and standards have been at the foreground of policy and practice discussions (e.g. [3, 14, 1]). However, research focusing on large scale educational implementation has established that "coherent instructional systems" have well-articulated purposes and visions [6]. Without a sense of the ambitious and clear purposes behind stakeholders' work, CS4All initiatives may lack direction and focus, which will have implications for equity in learning opportunities. Indeed, if CS education is to be 'for all,' it is incumbent upon the community to articulate the ambitious visions that will form the foundation for the changes in our education system that CS4All initiatives would require.

In this paper, we introduce a framework for examining what we call "CSed Visions;" particular arguments for and projected impacts of CS education and their associated pedagogical approaches. Our intention is to support educators, designers, and policymakers to consider how their initiatives reflect different ideologies and assumptions. The framework emerged from an effort to engage New York City-based CS education stakeholders in a participatory knowledge building (PKB) process [36] linked to these issues. The arguments articulated by stakeholders indexed various impact areas: (1) *economic and workforce development*, (2) *equity and social justice*, (3) *competencies and literacies*, (4) *citizenship and civic life*, (5) *scientific, technological and social innovation*, (6) *school improvement and reform*, and (7) *fun, fulfillment and personal agency*. Rather than each area representing arguments that are independent, our findings show that a given argument and vision for CS education may index multiple impact areas to varying degrees.

These preliminary findings represent a first step in developing a coherent "CSed Visions Framework" that links arguments and intended impacts to particular modes of CS pedagogy. Our intention is to create a resource that can be used to both design CS education interventions, as well as determine where needs exist that must be filled in order to make certain pedagogical visions possible. By recognizing, articulating and validating the many visions undergirding CS education, we hope to support individuals involved in CS4All initiatives to effectively deliberate around the needs they are intending to meet.

2. BACKGROUND
As current momentum grows around expanding K12 Computer Science education at city, state and national levels (see [15]), associated public narratives often assume that a core, underlying question has been sufficiently addressed: Why teach CS to all students? The most prominent public rationale has often been quite straightforward: making sure kids are "job ready on day 1," as President Obama stated in his 2016 State of the Union address and announcement of the national CS4All initiative [44]. And while stakeholders actively working in CS education rarely have such a unidimensional rationale, as many initiatives begin and as new actors arrive, having clarity around the core purposes these varied actors are envisioning is critical. Without clear "north stars," shared language, and pedagogical frames, CS4All projects

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may be like ships without compasses - setting sail without having a clear sense of where they're going.

Extensive literature on educational policy and implementation examining large-scale instructional reforms has underscored the importance of establishing clear guiding visions that at the center of what Newmann et al. [28] call "coherent instructional systems" a notion further developed by leading education policy implementation researchers (see [4, 6, 40]). Coherent instructional systems place various elements of educational implementation in relation to one another—teacher learning and professional development systems, instructional materials and assessments, and supplemental student support—ensuring that each is supporting the other. A clear set of goals and visions for both what the instructional system is meant to look like and what it is intended to achieve in terms of intended impacts forms the guiding force for the system [6]. This literature shows that underlying sets of goals and visions ensure ambitious educational initiatives are focused, and that elements of the overall system, including assessments, are aligned. Without articulated visions, however, large scale reform efforts are known to falter.

Within the CS4All movement, goal and vision setting processes have been led by both national actors as well as within specific implementation contexts. The Framework for K12 Computer Science Education focuses on identifying core CS concepts and practices students should learn—though the document does put forth a number of underlying visions of CS education associated with its project, including to "empower students" to "be informed citizens who can critically engage in public discussion on CS-related topics" and "learn, perform, and express themselves in other subjects and interests" [1]. Similarly, the Computer Science Teachers Association has developed a set of K12 Computer Science standards with associated rationale [41] and the AP CS Principles course has created a curricular framework [7]. More local goal-setting and instructional support frameworks exist or are in development, such as the New York City Department of Education's "CS4All Blueprint" [27] and the Massachusetts Digital Literacy and Computer Science Curriculum Framework [23] both of which attend to visions, learning goals and curricular commitments within those contexts.

The aforementioned documents draw on a range of different underlying arguments and associated visions for what CS education is meant to accomplish; however, such documents tend to state such visions at the outset, and then to move quickly to defining learning objectives and valued pedagogical practices. Currently, tools that themselves support vision-setting in the first place are lacking. In an effort to fill this gap, this paper outlines conceptual underpinnings of a "CSed Visions Framework" that is meant to offer stakeholders the possibility of integrating explicit deliberation around what kind of specific CSed Vision they are aiming to support in their work.

3. METHODS

In order to surface underlying arguments for CS4All, the authors purposefully sampled 24 New York City-based stakeholders in the CS education community, including informal educators, researchers, program designers, technology developers and policy makers. Participants—14 females and 10 males from diverse racial and ethnic backgrounds—attended a three-hour meeting, during which the authors incorporated participatory knowledge building (PKB) processes [36] oriented towards soliciting diverse rationales for CS education. PKB is a methodology that utilizes diverse stakeholder expertise as the basis for theory development and theory practice-linkages, drawing on traditions of participatory design [39], co-design [38], and design-based implementation research [29], all of which broadly position stakeholders as co-producers of knowledge as opposed to "research subjects."

First, participants wrote down arguments for universal CS education on separate sticky-notes. Teams of four-to-six participants then organized their arguments into named clusters. The second author, with participant feedback, then synthesized the 27 cluster headings, into 6 tentative argument categories. Next, participants formed new groups based on the argument they wanted to explicate and responded to written prompts the authors had prepared on online collaborative notepads. These prompts invited participants to articulate their chosen argument, to imagine the impacts should such a vision for CS education for all come to pass, and, finally, to provide examples of existing learning experiences (e.g., afterschool programs, classroom units) that they felt reflected elements of the arguments.

The findings presented here come from an iterative analysis of the arguments participants provided (161 sticky-notes); the content from collaborative notepads (6 pads); and the authors' meeting fieldnotes, sense-making discussions and then one additional member checking session where another 16 formal educators repeated the activity. Multiple rounds of inductive and deductive coding [34] were conducted during which categories were proposed, discarded and condensed in order to reach coherency. We took as our initial unit of analysis the individual arguments participants articulated on sticky notes, triangulating them whenever possible with content in the collaborative notepads and literature advancing similar ideas. An early insight from our analysis was that arguments clustered in one impact area index aspects of arguments that are more heavily related to other impact areas. The holographic quality of these arguments led the authors to take an interpretive approach to determining the 'central tendency' of a given argument, especially in cases where arguments seemed to entertain different variations on a theme. Our research questions were: What arguments are used to justify universal CS education? How do the various arguments conceptualize different impacts for universal CS education? Are there common impact areas these arguments all draw on?

4. FINDINGS

We identified seven non-orthogonal areas of argumentation for and projected impacts of universal computer science education: (1) *economic and workforce development* impacts, (2) *equity and social justice* impacts, (3) *competencies and literacies* impacts, (4) *citizenship and civic life* impacts, (5) *scientific, technological and social innovation* impacts, (6) *school improvement and reform* impacts, and (7) *fun, fulfillment and personal agency*.

4.1 Economic & Workforce Development

It comes as no surprise that many of the arguments participants surfaced made reference to jobs, the workforce, regional and national economies, industry pipelines, and human capital development. Arguments in this category took as their rhetorical center how beneficiaries (individuals, companies, industries, regions, nations) stand to gain economically from CS education. Such arguments also overlapped with components of arguments from other categories—namely from competencies and literacies, equity, and scientific, technological and social innovation.

For example, our participants echoed arguments made by prominent CS advocacy groups about how CS education can equip individuals with the specific skills needed to secure a job in the growing technology sector, as well as provide them with auxiliary 21st century skills (problem-solving, communication, collaboration) that will serve them in a range of careers [26, 46]. A twist on this argument posited that jobs in all fields will require some knowledge of CS, necessitating CS education even for students not interested in pursuing computing. Some arguments directly framed industry as the beneficiary, for example, the claim that expanding CS education allows companies to meet their growing needs for skilled workers. Other arguments were made on the basis of regional and national economic competitiveness; those localities offering CS education become more attractive to companies looking for a skilled workforce.

One set of arguments concerned the impacts that CS education might have on the ethnic, racial and gender diversity of talent pipelines to industry. While arguments regarding diversity may draw on rationales promoting equity, the primary objective of these pipeline arguments was to highlight the economic benefits that individuals, groups (including those underrepresented in technology fields), industries, companies and nations may receive from CS education. These arguments took many forms, depending on the ends they promoted. One suggested that CS education would provide opportunities for members of traditionally underrepresented gender, racial, and income groups to garner the skills and knowledge needed to gain employment in the technology industry. Such pipeline arguments might stop there, with the end goal of CS education posed as providing members of underrepresented groups "access" to existing structures of power.

Some "pipeline diversity" arguments, however, took "access" a step further, and more centrally spoke to equity impacts. While these arguments still cast industry as a central beneficiary of CS education, they suggested that by promoting inclusion of diverse voices in the tech industry, CS education has the potential to play a role in changing the nature of the industries, and not just to promote economic benefits: a more diverse workforce would prompt companies to adapt their cultures, hiring practices, pay structures and norms to address institutionalized sexism, racism, and classism in these industries. Reflecting rationales about technological and social innovation, some sets of arguments suggested that diverse teams in industry are better able to design and build products that cater to diverse customer bases, or, perhaps have an even more transformational and equity-oriented impact; informing the kinds of social issues and challenges that industry decides to address through the design of innovations.

4.2 Equity & Social Justice

Another set of arguments took as their central claim the importance of equitable distribution of various benefits associated with CS education—social, technological, economic, civic, intellectual, and otherwise. In some cases, these arguments went beyond equitable access and opportunity, suggesting that CS education could actively promote social justice impacts and the dismantling of social hierarchies.

Participants highlighted racial, gender and economic inequities in CS education and computing fields with phrases such as "the digital divide" or the "participation gap," disparities which have been well-documented in scholarly literature [10]. A range of reasons for these disparities have been investigated, including the culture of the technology industry and company recruiting practices [5], student preferences [37], lack of university-based support structures for particular populations [42], as well as the kinds of early exposures to computing various groups have access to [22]. The causes of inequities may be diverse and complex, but one of the more common arguments posited that expanding CS education could potentially "even the playing field" for members of underrepresented groups.

Some participants framed their arguments in terms of the benefit to individuals and groups—especially young women, youth of color and low-income youth—who might, through CS education, come to have more "choice" and "agency" in their career pathways and therefore experience economic "empowerment." We grouped this argument under an equity rather than a work-force related impact area because it frames individuals as agents who may choose to use CS skills in a variety of ways, perhaps acting within, or separate from mainstream technology careers. Such an argument privileges the need for equitable distribution of opportunities and resources over the need to diversify an industry pipeline or secure certain jobs for certain kinds of people.

Some arguments went one step beyond rationalizing CS education from an equity standpoint, envisioning how CS education might promote social justice. In some cases, these arguments reflected social and technological innovation and civic/citizenship rationales. They suggested that equitable participation in CS education would lead to the creation of technology that critiques social systems, supports social movements, and addresses issues rooted in non-mainstream and non-dominant values and experiences (see [11]).

4.3 Competencies & Literacies

Competencies and literacies arguments offered by participants often followed a common formula—a given competency is important for some broader reason—usually related to one of the other impact areas—and CS education is uniquely positioned to support said competency. We will not explore each in detail, but competency-related arguments generally covered the following: computational thinking, problem solving, creative computing and personal expression, systems thinking, critical technological literacies, design thinking, and other 21st century skills. We examine four here: computational thinking, creative computing, systems thinking and critical technological literacies—that exemplify the diversity of linkages that competency-based arguments can make to other impacts.

Many participant arguments related to *Computational Thinking* (CT), the prominent competency first offered by Jeannette Wing [47]. CT arguments were sometimes linked to workforce impacts—as one of our participants said, "computational thinking underlies every industry and discipline," and at other times were more linked to emergent forms of citizenship coming from literacy frames— "computational thinking as a form of digital literacy." Problem-solving skills were sometimes explicitly linked to CT arguments ("In the heart of CS is computational thinking… a very particular way of thinking about problems.")

Arguments related to *Creative Computing and Personal Expression* were also salient. These are long held perspectives within CS education scholarship, with notions of the "computer as a paintbrush" [32] indexing values around personal expression, voice and creativity. Participants spoke about "giving young people another mode of expression" and that "CS is a way for youth to creatively express their ideas + thoughts." Creative computing arguments have a strong linkage to the impact area of civics and citizenship, as social and civic participation is often connected to the ability to engage in personal expression. Somewhat less directly, emphases on "youth voice" linked to creative computing can also be understood as operating within discourses of equity and social justice, with creative computing competencies being linked to the ability to affect change around social issues young people care about.

Another competency-based argument centered on *Systems Thinking*—the ability to understand dynamics of, intervene in and/or design complex systems whose wholes are greater than the sum of their parts [36, 45]). Citizenship-oriented versions of this argument saw it as an important skill for simply participating in the world and in society—"CS is like biology—we are surrounded by systems that impact our life that run on it." Others focused more on what's framed as a societal need for systems thinkers given the scope of many complex global challenges such as global warming [43] and technological complexity [2]—that link more to scientific and technological innovation arguments.

Most explicitly linked to impacts concerning equity, social justice and issues of power were *Critical Technological Literacies*. These competencies relate to understanding the ideologies at play within the design of socio-technical systems, seeing how marginalization of particular groups could occur through design decisions, and "pushing back" against systems that do so [33, 35]. Participants spoke about how "people who can program computers (rather than just use them) will have the societal power," and directly referenced Rushkoff's notion of "program or be programmed" [35].

4.4 Citizenship & Civic Life

A fourth impact area related to notions of citizenship and civic life. Broadly, these arguments relate CS education to social, cultural and political participation, reasoning that an increasingly technologically mediated future might impact the ways citizenship is conceptualized. One common argument here related to *digital citizenship*, which articulates the need to prepare youth to participate in online contexts in productive and ethical ways [18], considering social norms around technology, as well as issues of privacy and online security. Related to these areas and linking citizenship to competency arguments were notions of *new media literacies* that young people need to participate fully in the new media landscape [19]. Taking "participation" a step further, some arguments viewed CS education as a vehicle for aforementioned critical technological literacy skills, suggesting that those informed about the values embedded in technologies will be better citizens, able to "push back" against technologies and sociotechnical systems they see as problematic or inequitable.

Other civic-related arguments linked to production-oriented views of citizenship—that CS education should support youth to be "creators not consumers" and "to build a society of creators," indexing logics of how young people should participate in a technologically mediated culture. Also linked to notions of cultural production were arguments that CS empowers youth to create projects benefiting their local communities, an idea with strong civic, equity and techno-social innovation undertones.

A final set of arguments in this area were about technological understanding as a prerequisite to citizenship. Examples here included arguments that CS education is needed in order to "deepen understanding of underlying technology," that "informed citizens need to understand the basics of how the world works in order to contribute productively to society as a whole." In contrast to conceptions of "digital citizenship" discussed earlier that were more bounded to contexts of "online" participation, these arguments indexed an assumption that general citizenship now required a certain base level of technological understanding.

4.5 Scientific, Technological & Social Innovation

Some arguments were linked to impacts on scientific, technological and social innovation and advancement. These arguments posited that CS education is either a pre-requisite for these forms of social advancement, or that CS education will enhance society's ability to produce such innovations. This logic was summed up by one participant: "More who learn CS → more production of new knowledge + innovations."

Within the context of these arguments, beneficiaries were conceived in a number of ways that link to other impact areas we've outlined. Linking to equity arguments, local communities can have greater capacity to address contextually specific problems through advancements in technology. Similarly, sub-groups that might have specific challenges, for example those afflicted by particular medical issues, can benefit from technological and scientific breakthroughs. Linking to economic and market-oriented arguments, consumers can benefit from better products while companies and industry can increase profits, market-share and allocate more resources to invest by being at the "edge" of innovation. Taken to its extreme, the entire human populace may benefit from scientific and technological innovations that solve "wicked" problems such as climate change, or "runaway" technologies or socio-technical systems [2], a notion that links to competency argumentation around the need for systems thinking. As one participant put it (admittedly in a tongue and cheek way), CS education will "save the world."

4.6 School Improvement & Reform

A distinct group of arguments focused on stakeholders within K12 education as beneficiaries—teachers, school administrators, and students (as they are today, not as future workers or citizens). Participants distinguished a few ways that CS education might work in service of broader school-reform goals. One argument assumed that since students are interested in new technologies and enjoy working with computers and mobile devices, CS education might increase student engagement at school. This was reflected in the statement: "school is boring, CS is interesting, school should be interesting. Do CS in school."

There is also evidence that there are inequities in the quality of the kinds of CS and STEM education programs that schools serving students from different socio-economic and racial backgrounds offer [25]. Thus, an argument for CS education for all may be "to promote equity in education." Other arguments suggested that tools and practices developed through CS might enhance students' learning of other academic disciplines (for example, introducing computer simulation of an ecosystem to learn concepts in ecology [25], or using CS concepts to learn algebra [24]).

Other arguments saw the potential for CS education to promote deeper changes to the pedagogical practices within schools. Recently designed curriculum for CS education requires students to learn in active ways: problem-solving around open-ended challenges, collaborating to design new and creative artifacts [13]. Some participants voiced the possibility that CS4All initiatives may bring additional professional development, training, and resources to support more active, hands-on teaching and learning.

4.7 Fun, Fulfillment & Personal Agency

Lastly, participants' arguments cast fun, fulfillment, and personal agency—for their own sake—as positive impacts for universal CS education. While the word "fun" did not appear in the dataset as many times as did the word "jobs," the concept was surfaced during both our initial meeting as well as during subsequent member checking sessions, with one group of formal educators framing "fun" as a rationale for CS education just "cuz." The notion that people might be intrinsically motivated to complete CS tasks such as programming is supported by survey data of self-described hackers who cite personal enjoyment as a core reason why they choose to engage in the unpaid work of improving and developing open-source software [24].

Participants' arguments also suggested the joy and fulfillment gained from CS activities might translate into "engagement" in the classroom. There is much literature on the educational implications of different kinds of student interest (as an example, see [16]), and design principles for digital media-based learning (including CS), such as the Connected Learning framework have centered youth interest as a core value and bridge to academic, economic and other opportunities [19]. In a report where researchers worked with youth and educators to determine measurable constructs for Connected Learning, "deepening satisfaction/fulfillment/joy" was framed as one of the core outcome areas [30].

Some of the arguments that surfaced in our roundtable took personal fulfillment one step beyond interest and enjoyment, focusing on how, as one participant put it, "constructing knowledge via comps [sic, computers] fosters agency." Another educator in the member checking session expressed the idea that "computer science allows you to make (program) anything that you want" whether that is an imaginative art object or something functional. "Creative computing" and "constructionist" visions for CS education, mentioned in the competencies and literacies section, also prioritize notions of personal choice and agency [32].

The sense of agency one stands to gain through CS education might also lead students to take action in civic life or for social justice. As one participant wrote, when students have access to computing they gain "increased agency to do what's impt [sic, important] to them." Others viewed this agency as key to empowering students to make decisions regarding careers, also indexing the economic and workforce development impact area.

5. DISCUSSION

Above, we identified seven central areas of argumentation and intended impact around universal computer science education surfaced by CS education stakeholders through a participatory knowledge building process. While there is still work to be done to systematically classify and understand the prevalence of certain arguments around CS4All, it is our hope that this work serve as a framework for analyzing projected impacts and beneficiaries implied by arguments that policies, organizations, programs, and pedagogies make about computer science education.

Even as there is great value in determining the most salient impact embedded in each argument, most of the arguments we examined were multi-faceted. This suggests that even if an argument envisions a particular kind of impact for CS education (e.g., the production of social innovations that address problems faced by marginalized groups), the strength of the argument may depend on proving possible impacts in other areas (e.g., the potential of CS education to promote diversity among those possessing CS skills).

Given the interdependence of the arguments from different impact areas, we recommend future research to evaluate both the validity of and assumptions within common CS education arguments. For which arguments are there strong warrants and evidence, and which are specious? Which arguments have been under-investigated? We also recommend that future research investigate the link between professed visions for CS education and on-the-ground, enacted pedagogies. To what extent do visions that tend towards a given impact area result in particular curricula, programs, and learning outcomes? Where do disconnects between "CSed Visions" and actual CS education pedagogies exist?

Different visions for CS education will also result in implementers looking to fill distinct needs. Policies rooted primarily in equity arguments, for instance, may require pedagogical approaches foregrounding particular groups (following models similar to groups like Girls Who Code and Black Girls Code), while ones rooted in career empowerment may need to establish internships with local companies, and a curriculum rooted in civic technology development may require connections between CS educators and community-based organizations or governmental actors.

We engaged a diverse, experienced, and knowledgeable group of CS education professionals in our participatory knowledge-building process. We do not, however, presume the sample of arguments which they generated represents all visions for CS education. That participants came from one particular urban setting is a limitation of this study. Going forward, there is a need to involve more communities— including parents, youth, formal educators, and stakeholders from a range of localities—to test and refine the framework we have developed here, and to continue surfacing the multiplicity of visions driving CS4All initiatives.

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