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"Growing as a person": Authoring Identity Across Formal CS Education and Everyday Computing Contexts

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Abstract: To understand how learners develop identities in computer science (CS), we must investigate learners' experiences with computing throughout their lives. Drawing from a theory of learning as participation in communities of practice, we analyze interviews with high school students at the end of their time in a 2-year, constructionist CS course to better understand how these students' CS education affected their experiences with computing in their everyday lives. We identify moments where students begin to "re-see" technology which offer insight into how students author their computational identities. However, our analysis reveals that re-seeing does not inevitably align with a positive trajectory of participation in CS. Instead, we discuss how the nuances of students' "re-seeing" experiences combine with various social factors to influence students' computational identity authorship.

Introduction

As computer science (CS) education expands in K12 education around the world, there is a growing opportunity–and a growing urgency–to design for CS learning experiences which positively influence learners, their communities, and the world. Traditional measures of content learning will not be enough to ensure that CS learning experiences have a positive influence; we cannot simply ask, "Are students learning CS?" Instead, we must focus on what learners need in order to participate in a world where computation plays an increasingly significant role. In addition to supporting participation in computing, CS education must prepare learners to decide *whether* and *how* to participate in our increasingly computationally-mediated world (Vakil, 2020; Ryoo et al., 2020). As a practice which helps learners recognize, make sense of, and solve computational problems, Wing's (2006) Computational Thinking (CT) has become the most common way to describe how CS might help learners solve real-world problems. While early work largely understood CT as an individual cognitive phenomenon, more recent frameworks also recognize CT as a social practice embedded within systems of power (Kafai et al. 2020). In these framings, learning is understood in terms of participation in communities of CS practice. Identity is a central construct which models the processes by which learners show up and act in a community of practice. If CS education is to prepare youth to participate in and help shape our computational futures, we need a better understanding of how learning environments support learners in developing computational identities (Penuel and O'Connor, 2018; Kafai 2016; Tissenbaum et al. 2019; Dindler, et al., 2020). Because learners' computational identities extend throughout their lives, we must investigate this construct across formal CS education and everyday computing contexts. Such an investigation can help us understand the roles that formal CS education can play in learners' broader lives and help us provide resources to learners as they negotiate their computational identities. In this paper, we present a phenomenographic analysis of beginner high school CS students' experiences negotiating their computational identities. In analyzing these experiences, we highlight the ways students feel their CS education contributes to this experience, supporting or constraining them in their use of technology. In doing so, we contribute to an understanding of computational identity that spans both formal CS education and everyday computing contexts.

Background

Our definition of computational identity begins with the understanding that learning happens through participation in communities of practice (Wenger, 1999). In order to characterize learning as a process of social participation, this framework outlines four components of learning: (1) doing, (2) belonging (3) experiencing, and (4) becoming. In this framework, the process of becoming is interconnected with the processes of doing, belonging, and experiencing. We are constantly developing identities (both our own and others') through our actions, which are in turn dependent on our positions and experiences within the community. How we position ourselves relative to others in a community of practice allows us to author our identities (Holland et al., 1998). At the same time, identity authorship is also restricted by the ways other members of a community of practice

recognize (or don't recognize) our participation. This development of identity through practice is rarely linear, instead consisting of many fluctuating moments where learners feel stronger or weaker identities relative to a field. Applying this framework to the work of a CS course helps us to see that course as situated within many different community contexts including the classroom, learners' home environments, and even digital spaces like StackOverflow. Identity development in CS has been charted as learners experience success and failure (Dahn and DiLiema, 2020), join or get excluded from communities of practice (Shaw et al., 2021; Margolis et al., 2008), and face stereotypes about who can be successful in the field (Love et al., 2021). This development is not always ultimately positive. Learners' participation in computing communities of practice can create distance in their computational identities, either because they feel incapable or uninterested in participating (Kang et al. 2019) or because the computing communities of practice are exclusionary (Nasir and Vakil, 2017).

Learners' experiences in communities of CS practice, both positive or negative, contribute to their trajectories of participation in the field of CS (Drier 1999). These trajectories of participation take into account learners' positions in communities of practice as well as the ways they navigate between different communities of practice. As learners have experiences in these communities, they develop expectations (of the discipline and of themselves) that determine what they see as possible and appropriate forms of participation in computing communities of practice. Rather than being deterministic, trajectories of participation should be seen as the resources and constraints that influence learners' perspective on what are possible forms of participation in their communities of practice. To investigate the process of identity authorship through participation, we are particularly interested in moments where learners feel their perspectives are shifting–moments where learners are "re-seeing" their computational worlds and their place in them (Silver, 2014). To paint a full picture, we must understand this re-seeing in formal computing settings and across multiple everyday uses of computational tools and ideas (Shaw and Kafai, 2020). With this in mind, we are interested in the following questions:

1. How do the ways learners use or feel about technology change as they learn CS?
2. Is there a relationship between these changes and how learners author their computational identities?

Methods

This study was conducted at a private bilingual K-12 school in Hong Kong, where twenty-eight ninth graders participated in a two-year curriculum. In this cohort, thirteen consented to participate in this research (14-16 years; three girls, ten boys). The central goal of the course is to "create a rich, diverse community of people making things with code, through which they can develop personal relationships with powerful ideas" (Proctor et al. 2020). The course was composed of six units (e.g. computational art, data science, web development, etc.); for each unit, students completed an open-ended project that applied skills and concepts from that unit.

At the end of the program in May 2021, three researchers who were also teachers conducted a semi-structured exit interview with each student. We asked students to reflect on formative moments with technology throughout their lives as well as changes in their relationship with various technologies (such as the internet and their computers) over the course of the two years. With these interviews, we extend Wilkerson et al.'s (2020) methodology for locating computational thinking in everyday spaces of learning to identify "locally constructed definitions" for identity in CS (p. 269). To analyze the data for this paper, three of the authors conducted a thematic analysis and identified students' reflections about the computational world and their place in it. One author then re-coded the interviews to identify all instances of "re-seeing" the computational world, drawing from students' own language to create the category. In this paper, we seek to capture the experience of our students as individuals rather than summarize across the class. We contribute these select perspectives to the literature on identity in CS education while laying the foundation for future work to explore broader categories of perspectives in our class and other populations. Students' names have been changed for anonymity.

Findings

Re-seeing the computational world

Though they had a wealth of experience with technologies from gaming PCs to learning management systems prior to the course, students frequently reported a change in their interactions with technologies during their exit interviews. Reflecting on watching a music video on a Virtual Reality platform, one student, Tina, said:

> "It made me think more about what I was using and what I was doing. And like the interaction between person and digital device, that kind of relationship. . . Like, "oh," if I click on this button, there's a whole bunch of code behind the color of this button and the depth to make it look like a button. And this button links with some other page. And it's like a whole process of coding and effort for me to just click on a button to get to a new page."

In total, we found that in ten of the thirteen student interviews we analyzed (77%), students discussed an experience where they used technology differently or felt differently about technology compared to their experiences before the course. Many, like Tina quoted above, described a realization of the many layers through which their interactions with technology flowed, unveiling servers behind web pages and file systems behind graphical user interfaces.

Re-seeing and computational identity authorship

Along with their shifting perspectives, some students described enacting this perspective as part of their computational identity authorship. During the data science unit, one student, Noa, chose to find her own datasets to answer a question about her experiences as a competitive athlete in a water-based sport. This experience was a critical moment in Noa's trajectory as a computer scientist. After completing the project, she went on to do a variety of data analysis projects that were connected to her interests in the ocean and in sustainability. In her final interview, she connected all of these experiences back to the data science project, saying, "the data science [project] actually helped [her] develop as a person," and "doing data [science] led [her] on to give [her] the opportunity to do [a conference publication] and many other projects developed after that." Reflecting on these experiences and how she developed over the two years of the course, Noa said:

> "I think a lot of it was character development, me growing as a person and as I mature, I feel I'm being more aware of the people around me, and the events happening around me... I'm actually doing more service. I want to do more for the world."

Though many students, like Noa, shared ways that their re-seeing experiences were connected to positive trajectories of participation in CS, students also shared examples of the ways their experiences affected their trajectories in negative ways, making them feel less confident and less excited to continue learning CS. For example, Tina noted that she respected people in CS "because it's very difficult" and described how in the first year of the course she began thinking that she "might not be built for computer science." This feeling extended through her final project of the class in the web applications unit. Looking around at the other projects, Tina felt like other students were progressing more quickly than her and her partner. For Tina, CS is "an interesting topic, but [she is] not necessarily enthusiastic about it compared to other people." In contrast with Noa's experiences, Tina's comments highlight the ways that she feels separated from others practicing CS.

Discussion and future work

Our findings highlight the cognitive shifts that occur when our students "re-see technology" in their everyday interactions. However, considering how changing perspectives affect students' identity, we interpret the act of "re-seeing" as a series of social negotiations that ultimately affect trajectories of participation in CS. Indeed, students' perspectives of technology were always changing within their communities of practice; they were "re-seeing" as they were doing, becoming, experiencing, and belonging (Wenger, 1999).

For students like Noa, their changing perspective on CS promoted a positive trajectory of participation in CS. However, this was not always the case. Even while developing a new perspective in CS, some learners' experiences were connected to a negative trajectory of participation. Tina's experiences offer a particularly interesting case study. Like many other students, Tina described the ways her CS education helped her see new features of technology. However, for Tina, this complexity still represented something she felt she would never understand. Tina's comments about feeling like "she wasn't built for CS" based on her perceptions of the field and on her experiences in the class align with research showing how stereotypes that students and educators hold about CS can limit learners' participation in the field (Love et al., 2021). At the same time, Tina's comments that CS is "an interesting topic, but [she is] not necessarily enthusiastic about it" do not seem flippant. Throughout her interview, Tina described ways that she imagined her CS education could serve her in the future and even sent a follow-up email to her interviewer clarifying that she felt her CS education had positively "changed [her] thinking about learning." This leads to another reading of Tina's experience: that given what she knows about CS and about herself, Tina decides to limit her engagement with the field. Though her formal CS education has not (yet) culminated in a positive trajectory of participation in CS, Tina is still negotiating her computational identity by refusing further engagement with CS education. While these two readings of Tina's negative trajectory are different, we believe that both are necessary to make sense of Tina's computational identity. We are critical of the ways the course community of practice contributed to Tina's sense of exclusion, *and* we recognize the agency Tina exhibits in refusing to participate further.

While Noa's and Tina's examples represent different trajectories of participation in CS, they both describe kinds of computational identities assumed by students, the experience of these identities in students' lives, and the CS education resources that influenced students to take on these identities. However, these examples represent just two of many in our data. In future research, we plan to use these insights as a foundation for further exploring how students' experiences with computing shift as they learn CS and for determining how specific experiences with CS education influence students' computational identity authorship. As technology increasingly intersects with problems in our world, this research is essential for designing CS education that prepares learners to participate in the world with the intention and ability to use computing as a force for good.

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