Evaluating the Impact of a Smart Greenhouse Intervention on Interest and Identity Using a New Framework

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Abstract: A mixed methods study of a 14-day computational-thinking-and-computer-science-infused environmental science intervention observed 193 middle schoolers to engage behaviorally. Based on self-reports and observations, some students increased coding and computer science (CCS) interest and negotiated CCS identity. New criteria for the study and evaluation of identity development, strongly related to interest development, may provide a useful framework for other interventions intended to broaden computational participation.

Infusing computational thinking (CT) in science classrooms benefits from fostering a lasting, positive CCS identity, particularly for students from non-dominant populations (Kafai, 2016). This 14-day, CT-infused intervention was designed to teach CCS content and support student CCS interest and identity. Content included students building automated tabletop greenhouses capable of small-scale urban farming. In pairs or trios, students wrote MicroPython code for a Wio Link ESP8266 board which they connected to actuators, sensors, and displays, applying new CT and CCS skills to collecting data and controlling environmental variables for their basil, cilantro, or lettuce plants. Such content related to identity in that, "[p]rogramming is not an abstract discipline, but a way to 'make' and 'be' in the digital world" (Kafai, 2016, p. 27).

Theoretical frameworks

Hidi and Renninger (2006) inductively found interest to develop over four fluid phases. In Phases 1 and 2, individuals attend to content fleetingly, whereas in Phases 3 and 4, students show "enduring predisposition to re-engage content" (p.111). *Interest* intersects with *identity* where these constructs share markers. *Identity resources*, in signaling to students who they are and can be, are the main mechanism by which identities become available in science-learning environments (Pinkard et al., 2017). Nasir and Cooks (2009) describe three interrelated types of identity resources – *material*, *relational*, and *ideational* – upon which three new criteria for development of students' CCS identity were based. Criterion 1 was the provision to students of the three types of identity resources: *material resources* of the curriculum on the design of an automated greenhouse and investigation of scientific questions, *relational resources* of student-teacher relationships and teacher-assigned work groups, and *ideational resources* of teachers' beliefs affording space for students to exchange ideas. Table 1 details what students could do with the design affordances from Criterion 1 to develop their CCS identities.

Table 1: Framework for Identifying Student Usage of Identity Resources, Including Phases of Interest, Abridged

	Material Resources	Relational Resources	Ideational Resources
Criterion 2 (C2): Use of identity resources	Students first engage with curriculum, re-engage (Phase 2). May repurpose curriculum.	Students develop extended work partnerships with teachers and each other.	Students position selves in CCS (Phase 3), & negotiate CCS identity.
Criterion 3 (C3): Sustained use of identity resources	Students re-purpose curriculum, applying it to other contexts, e.g., at home (Phase 4).	Students have long term relationships and networks in CCS (Phase 4).	Students have lasting, "sticky," ideas about who they are in CCS (Phase 4).

Note: "Phase" refers to the four phases of interest found in Hidi and Renninger (2006).

Material Resources (C2, C3) describe how a student might, over time, shift her relationship to CCS content through curriculum materials. A student may start out with perfunctory behavioral engagement (C2) but as she develops expertise, she may also begin to deepen her interest. When a student realizes she is re-engaging content independently (C3 and interest Phases 3-4), knowing that she has turned to the same content repeatedly in the past supports her believing that she would continue to do so in the future, helping her to further identify with CCS. *Ideational Resources* similarly progress from less likely to re-engage without support (C2) to highly likely to re-engage (C3), in this case with ideas about CCS content as well as who one is in relation to CCS (e.g., beliefs, goals, and hopes about oneself in CCS). *Relational Resources*, which may be the most impactful, as disciplinary relationships are crucial to defining one's disciplinary identity (Pinkard et al., 2017), progress from structured, compulsory participation with others (C2) to voluntary and externally-affirmed participation (C3).

Research questions and study design

Our research questions were whether changes occurred in students' (1) CCS Interest, or (2) CCS Identity. In an explanatory design, data from surveys (pre, post), interviews (pre, post, five-month follow-up), and observations provided evidence to use Table 1 as a rubric to answer the research questions. From 193 students (m=95, f=94, non-binary=4; Latinx=88, White=70, other=35), 16 focal-group students were selected for deeper scrutiny based on differences in pre-interviews and -surveys on CCS confidence, proficiency, and prior experience as well as long-term scales on *CCS Identity* (*items*=12, α=.88), and *CCS Interest (items=12,* α=.92).

Results and implications

Before the intervention, Latinx students reported less frequency of prior experience than White/other ethnicity students [65% vs. 85%, $F(1, 118) = 1.412$, $p = .027$]. Long-term *CCS Interest* and *CCS Identity* scale scores did not change statistically significantly (for all students, by gender, or by ethnicity/race), but did show gains in reliability. Shorter-term, qualitative results supported interest and identity development.

One student's experience in the greenhouse intervention exemplified different criteria for identity development being met or considered. Gal (names are pseudonyms) began with no prior CCS experience, low interest, and a stereotypical, male-gendered idea of coders as "some weirdo sitting in a room typing on his computer." During the unit, Gal *used* relational identity resources (C2) when she coached a worried friend, Mae. In turn, Mae *used* relational identity resources when she encouraged Gal's interest in coding a robotic arm. Gal then *used* the material identity resources (C2) of robotic equipment when she independently re-engaged with coding in experimentation with the robotic arm. The coaching opportunity may have helped Gal to develop the ideational identity resource (C2) of understanding that CCS takes "determination, perseverance, and optimism." Gal's attainment of Criterion 2 for all identity resources supported the conclusion that her CCS identity developed during the intervention, as did her interest. In the post interview, Gal had a new, non-gendered conception of coders as scientists who make "gadgets" for useful automation. She pondered a later scientific investigation with her partner (C3, Material and Relational Identity Resources), but, five months later, had not done it. Gal still considered herself highly interested but felt a bit "less" CCS identity than after the unit, perhaps due to a lack of opportunity to re-engage in any CCS projects that could have re-triggered interest.

Our analysis of the 16-student focal group found that the combination of *presence* (C1) and *use* (C2) of identity resources shifted students' ideas about what mattered in the content and who they were in relation to it. All students achieved piqued interest; none were indifferent. Some were observed using ideational identity resources when they proposed, defended, and revised ideas on greenhouse design. We believed that the use of relational identity resources had potential for lasting impact when students felt safe enough to critique and build upon each other's ideas, particularly when their partners were also their friends, a relationship that would outlast the unit. Students adopted ideas about what is valued (e.g., in greenhouse design) as well as enacted practices (e.g., idea-generation, critique) to decide who one is and can be in CCS. The quality and quantity of the interest that students discussed in their follow-up interviews suggested that the spaces where students applied CCS to the greenhouse problem, in being pushed into public view as a site for active negotiation, aided in identity development (Nasir & Cooks, 2006; Pinkard et al., 2017). Aligned with Gal's outcome, other students attributed drops in interest and identity to not having more CCS activities to do after the curriculum unit had ended.

This work went beyond an existence proof that CT can be embedded into mainstream science classes, towards organizing an understanding of identity resources, strongly related to interest, to support students' developing CCS identities. We believe that this intervention showed potential for impacting students' CCS interest and CCS identity development, specifically through the provision, engagement, and re-engagement with high-quality material, relational, and ideational resources. We believe that in the future, using these newly-developed criteria not just for evaluation, but also as targets or goals for curriculum design, would help to create curricula that support the development of students' CCS interest and CCS identity.

References

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