

# Exploring the Use of Virtual Identities for Broadening Participation in Computer Science Learning

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**Abstract.** This paper reports on a design-based research study investigating the impacts of virtual identities on public secondary school students in a computer science learning workshop targeting groups currently underrepresented in STEM disciplines in the United States. Using grounded theory methods, results from three workshops were analyzed to address (1) how to characterize the relationships between learners' virtual- and physical-world identities and (2) the impacts of avatar use on students' performance and engagement in computer-based learning environments. The central results are characterizations of four types of relationships between students and their virtual identities that we term (1) *Strategic Investment*, (2) *Avatar as Tool Investment*, (3) *Avatar as Self Esteem Measure*, and (4) *Judging Context Appropriateness*, each with implications for establishing design principles for STEM learning environments utilizing virtual identities.

**Keywords:** Computer science education · K-12 · Virtual identities · Immersive learning · Videogames · STEM identity · Avatars · Education · Self-efficacy · Computer ethics · Career · Programming · Human-computer interaction

## 1 Introduction

Educational technologies such as adaptive learning systems, educational games, and Massive Open Online Courses (MOOCs) have proliferated. Nearly everyone who uses a computer also uses a virtual identity, e.g., social media profiles, online shopping accounts, videogame characters, avatars, and more. Given the widespread use of such virtual identity technologies in educational technologies, it is important to better understand their impacts on, and interrelationships with, physical-world identity and behavior and to establish innovative and best practice in their design and deployment. We seek to discover best practices for using virtual identities to enhance performance, engagement, and STEM identity development for public secondary school students from

demographic groups currently underrepresented in STEM disciplines in the United States (focusing on African American, Caribbean American, Latinx, and female students). Towards this goal, this paper reports on results from a series of computer science learning workshops deployed to address how to characterize (1) the relationships between learners' virtual and physical-world identities and (2) the impacts of avatar use on students' performance and engagement in computer-based learning environments.

## **2 Theoretical Framework**

### **2.1 Learning Sciences**

The key approaches from the learning sciences that were drawn upon in the design, implementation, and analysis of this intervention were (1) critical pedagogy theory, (2) constructionism, (3) approaches to computational literacy, and (4) grounded theory.

Well-known work in critical pedagogy theory [1] emphasizes a notion of dialogue as a pedagogical practice in which co-construction of meaning occurs when educators and students identify and engage hopeful vocabulary with the possibility of social empowerment. In this approach educators and students share ideas horizontally with mutual trust. Building on Piaget's venerable constructivist theories of cognitive development, his protégé Seymour Papert applied this lens on pedagogy to develop the approach termed constructionism. Constructionism is now commonly applied both as a pedagogical philosophy and technique in which building objects is central to the process of learning, and [2] furthermore, the public sharing of these built objects with others is seen as crucial to learning as it provides a sense of increased accountability [3].

Computational literacy is an emergent form of literacy that will "have penetration and depth of influence comparable to what we have already experienced in coming to achieve a mass, text-based literacy" [4]. It involves both using and, crucially, producing computational technologies. This project focuses not only on the learning of the building blocks of "literate programming" but also on "computational literacy" [4], and more generally, "procedural literacy," defined as facility with activities that "encourage active experimentation with basic building blocks in new combinations" [5][6].

Finally, Glaser & Strauss' grounded theory methods [7] provided an inductive approach to systematically generating conceptual categories from the data that is synergistic with a critical pedagogy approach to supporting student empowerment and agency. This process of seeking to meaningfully describe student-avatar relationships without imposing prior theoretical assumptions entailed a hermeneutic approach to the study of human conduct [8]. This approach involves preparation through minimizing preconceptions, data collection, coding, memoing, and the conceptual sorting of memos.

With regards to content development, the intervention in this project is aligned with the influential Exploring Computer Science (ECS) Curriculum [9]. This intervention adopts elements of Units 1-4 of the ECS curriculum: (1) Human-Computer Interaction (especially connections among social, economic, and cultural contexts), (2) Problem Solving, (3) Web Design (including social responsibility), and (4) Programming.

## 2.2 Physical-World, Virtual, and Blended Identities

Prior research on player-avatar relationships (PAR) describes the human and non-human, physical and digital, material and immaterial parts that are “broken down and rebuilt” [10] during avatar creation, customization, and use. Harrell and Veeragoudar’s prior study of the relationships between underrepresented students in STEM and their avatars in learning games [11] characterized students’ perceptions of the construction and use of their avatars across three dimensions: (1) avatar appearance, with preferences ranging from everyday to extraordinary categories, (2) avatar ontological status, with perceptions ranging from first-person mirror representations to third-person external representations, and (3) avatar use, with uses ranging from deployment as instrumental tools to a means for imaginative identity play. In related work, other studies are useful for reinforcing and broadening these three main dimensions more generally to PAR as a player’s (1) identification with their avatar, (2) attachment to their avatar, and (3) perception towards the avatar’s instrumentality [12][13], describing the degrees of self-similarity, affinity due to likeness, physical control, responsibility, and suspension of disbelief [14], and usefulness that players perceive their avatars to have [15].

Given the broad range of possibilities afforded by avatar creation and customization systems, extensive research has also been performed to better understand the motivations and behaviors of players in their selection of character traits for their avatar across artistic, psychological, and technological factors. In seeking to better understand the ways in which players’ physical and virtual world identities are blended through the personalization process, Harrell’s notion of blended identity [16] provides a mapping between aligned aspects of a player’s physical identity (e.g., actions, characteristics, capabilities), the virtual identity (e.g., technical system affordances and properties), and blended identity (i.e., the playable character which is under the scope of user control).

## 3 Methods

### 3.1 Participants

Participants included Cambridge and Boston, MA public school students recruited through partnerships with the schools and via a collaboration with a non-profit organization called Innovators for Purpose. The majority of participants were enrolled in introductory computer science courses. The first workshop included twelve middle and high school participants. All twelve self-identified as “Black or African American;” four self-identified as female and eight as male. The second workshop included seven high school participants, four self-identified as “Hispanic or Latino” and three as “Black or African American;” four participants self-identified as female and three as male. The third workshop included seventeen high school participants, thirteen self-identified as “Black, Caribbean, West African, or African American,” and four as “Hispanic or Latino;” fourteen self-identified as male and three as female.

### 3.2 Materials and Procedure

The workshops used both paper-based and digital materials to facilitate student learning of fundamental computer science principles as well as ECS topics such as human-computer interaction, privacy, and security. This included books with design examples, sticky notes for ideation, grid paper and markers for paper prototyping, index cards and pens for documentation, feedback, and game testing, and computer equipment with a high-speed internet connection. A key component of the study is a computer science learning platform developed in the MIT Imagination, Computation, and Expression Laboratory (ICE Lab) called *MazeStar*, the features of which include tools enabling learners to create customized games [17]. A key component of *MazeStar* is *Mazzy*, a game in which players solve mazes by creating short computer programs. In our workshops we use *MazeStar* as a platform enabling students to address issues of their own concern within their communities through design. *MazeStar* and *Mazzy* provide an experimental setting in which the authors have conducted evidence-based research to better understand the impacts of avatar use in students' learning.

### 3.3 Data Collected

Activities were videotaped and audiotaped and all computer monitors were screen-captured. Avatar customization actions were logged by the AIRvatar system, a custom telemetry system to capture data about user avatar customization [18]. All paper-based student materials were collected and photographed. In-game performance data and student survey data (regarding topics such as students' demographics and dispositions toward computer science) were collected. Individual semi-structured clinical interviews were conducted roughly one month after the workshop.

### 3.4 Data Analysis

The following procedure describes the qualitative research strategies from grounded theory methodology which were employed to analyze student discourse data. In preparation for the analysis process, we created a matrix of student data. Individual researchers performed open conceptual memoing of student transcript data. This enabled broad ideation and evaluation of emerging theories throughout the analysis process, ensuring all student discourse artifacts (e.g.: workshop transcript, interview notes, screen capture images) were openly coded prior to applying external theoretical models. Next, individual researchers applied an existing coding scheme to interpret the analysis matrix populated with the data provided by the students during the workshop and follow-up interviews. The coding scheme which was applied is a subcomponent of a validated instrument called the Advanced Identity Representation (AIR) Inventory. The AIR Inventory was developed to systematically annotate empirical study data of identity creation in video games to support the emergence of coherent theories from voluminous collections of verbal, textual, survey, and video data. The MIT ICE Lab developed the initial instrument in 2011. Iterative, accretive development of the advanced instrument was achieved through several rounds of user studies, validating its usefulness as a rubric

for recognizing and characterizing moments of conceptual flux in subjects' spoken references to their avatars, particularly regarding to subject/object status.

An additional round of analysis was performed by applying a finer-grained coding scheme from the AIR Inventory. Utilizing grounded theory techniques, aggregates of discourse-based evidence resulted in concepts and theories articulating characterizations of four types of relationships and emotional connections between students and their virtual identities, described below in the results section. Finally, group discussions facilitated the synthesis of individually-constructed memos and codes, allowing the most significant themes to emerge. The integration of both individually- and group-constructed codes, themes, and analyses was systematically performed until core categories were identified upon reaching "theoretical saturation" [20]. The core strategies identified through this extensive analysis process are described below.

### 3.5 Results

Analysis of over 40 hours of transcribed interview data yielded four characterizations of the relationships between students and their virtual identities were elicited from the study data, which are (1) *Strategic Investment*, (2) *Avatar as Tool Investment*, (3) *Avatar as Self Esteem Measure*, and (4) *Judging Context Appropriateness*, each with implications for both future studies and for establishing design principles for STEM learning environments utilizing virtual identities. Consistent evidence of three phenomena emerged from the study results: (1) Likeness Bias (a significant bias towards the "authentic" self, and a stigmatization of identity play/tourism), (2) Avatar as Object (a subset of students use avatars strictly instrumentally), and (3) Importance of Context (students strongly preferred avatars that they deemed suited to the game genre/fictional virtual world at hand). These results are elaborated in Table 1.

**Table 1.** Results Summary: Characterizations of four types of relationships and emotional connections between students and their virtual identities. Note that the example narratives excerpts have been selected from a larger body of evidence transcribed from student interviews.

	<i>Phenomenon description and relevant avatar user types</i>	<i>Projection between physical-world and blended identities</i>	<i>Example student narrative excerpt from student transcript data</i>
<b>Strategic Investment</b>	Students invested in effort to ensure that their avatars resembled them and described emotional attachments to their avatars, but also claimed to be emotionally disinvested in avatar features	<p><u>Projected from physical identity to blended identity</u>: Physical-world attributes: skin color, hair, nose, color preference, religion, and so on.</p> <p><u>Projected from blended identity to physical world identity</u>: Sense of investment; limitation acceptance; disinvestment</p>	"I made mine, like myself...the problem would be like, I don't know, the nose, I guess. But everything else was fine...the hairstyles, or the skin color, and it kind of disappoints me a little bit, but I know it's hard to get the exact details of every single thing. . . I kinda, I don't worry about it too much, so I just try to make it look like me as much as possible...I would like to have, I kind of get a little mad, but

	that they were unable to customize adequately due to limitations of the avatar creator; Mirror; Identity-Player.	in avatar mirroring; reason for degree of (dis)investment.	I don't, I don't get worried about it that much."
<b>Avatar as Tool Investment</b>	Students who use avatars strictly instrumentally (and not for identity play) still see the type of avatar as likenesses of their physical-world identities in terms of the types of tools or playthings they appropriate to their social category; Mirror; Instrumental-User.	<u>Projected from physical identity to blended identity</u> : Instrumental control, in addition to items mentions for <i>Strategic Investment</i> . <u>Projected from blended identity to physical world identity</u> : Sense of appropriateness of the tool to social identity; relationship to avatar as object.	"I would have easily found something I was happy with, whether or not he looked similar to me or was a polar opposite. Because as long as I think he looks cool, he or she looks cool, probably he, as long as I'm okay with it, I don't feel a need to make him to look like me so I don't really feel like it would have impacted my experience in building the map at all...in the workshop...I didn't really feel like the character had a significant effect on one making the game or two playing it...So he kind of just became an object that I was moving around."
<b>Avatar as Self Esteem Measure</b>	Students consistently suggested that a desire to create a non-likeness avatar reflected a lack of self-esteem; Mirror; Identity-Player/Instrumental-User.	<u>Projected from physical identity to blended identity</u> : Personal history/attachment (e.g., nostalgia, repeated creation of same character), in addition to items mentions for <i>Strategic Investment</i> . <u>Projected from blended identity to physical world identity</u> : Self-esteem.	"I feel that they [players who create characters that do not look like themselves] don't care about themselves in the real world, and they want to express their new life in the game and be someone completely different than in reality...They don't really like who they are."
<b>Judging Context Appropriateness</b>	Students strongly preferred avatars that they deemed suited to the game genre/fictional virtual world at hand - they also associated preferences for genres/fictional world types with their physical world identities; Mirror;	<u>Projected from physical identity to blended identity</u> : Range from no customization at all (only control) to context-specific adaptations in addition to items mentions for <i>Strategic Investment</i> . <u>Projected from blended identity to physical world identity</u> : Sense of genre	"Um, for sports it's probably different 'cause I try to make it, like, I guess as the best athlete as possible. So you know...height and strength, and whatever. That's what I try to do for sports...when I do the sports one I try to make the avatar as, like, make it look like an athlete with the muscles and height...When it's like, uh, like a game that has, like an adventure or something like that, I would usually, I would make it like me. Like, me, you know."

Everyday/Extraor- dinary Appearance/Context.	preferences, sense of real- ism/illustration prefer- ences (e.g., anime style).
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## 4 Conclusion

This study has resulted in more nuanced ways to characterize the relationships between learners' virtual and physical-world identities and revealed characterizations of four types of relationships and emotional connections between students and their virtual identities. Our findings suggest that developers must take seriously students' potential social and emotional investment in avatars that represent students' physical-world identities. Although many students initially stated that "it doesn't really matter how the avatar looks," in practice these students invested a significant amount of effort to customize their avatars to look like themselves. Furthermore, use of likeness avatars has been shown to impact students' performance [21]. In fact, across a number of conditions in prior work, participants using *successful likeness* avatars (showing a likeness avatar when is successful and shape otherwise) were the highest performing out of all conditions, while (like here) self-reporting did not reveal a difference in engagement [22]. We found that participants take up a strategic form of engagement when their customization aspirations are thwarted by the avatar creation systems' affordances.

In conclusion, we recommend that developers be intentional in the design of virtual identity creation systems in order to build empowering computer-based learning platforms and environments for young learners. Considering *Strategic Investment* means affording learners ways to more meaningfully map traits from physical- to virtual-world identities. Per *Avatar as Tool Investment*, designers must acknowledge the identity-laden effects of color, shape, and other properties on the perception of even the most generic and abstract avatars. Acknowledging *Avatar as Self Esteem Measure* means ensuring platforms support designing diverse likeness avatar representations. Finally, addressing *Judging Context Appropriateness* suggests providing graphical embellishments that fit both the game domain theme *and* student interests. Taking such design implications into account supports not only creating systems more equitable to diverse learners, but systems that better enable learners' sociocultural identities to be powerful resources for their STEM identities.

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