Paper Title Can I Be a Mathematician and Computer Programmer? Identity-Building Through Moments of Playful Talk (Poster 2)

Author(s) Amy Rae Johnson, University of Texas at Austin; Sylvia Celedon-Pattichis, University of Texas at Austin; Marios Pattichis, The University of New Mexico; Hakeoung Hannah Lee, University of Texas at Austin; Esteban Cantu, University of Texas at Austin; Carlos A. LopezLeiva, University of New Mexico

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Can I be a mathematician and computer programmer?: Identity Building Through Moments of Playful Talk

Amy Rae Johnson, Sylvia Celedón-Pattichis, Marios S. Pattichis, Esteban Cantú Jr., Hakeoung Hannah Lee, Irán Tovar, and Carlos LópezLeiva

University of Texas at Austin
University of New Mexico

Introduction

Mathematics and computer programming (MCP) are often viewed as distinct subjects when explored in K-12 spaces (Celedón-Pattichis et al., 2013). Elementary school students, especially those from marginalized groups, have limited access to computer programming curricula in school. In addition, much has been researched related to how students construct and negotiate their mathematics identities (Aguirre et al., 2013; Darragh, 2016; Graven & Heyd-Metzuyanim, 2019), but less has explored the relationship between MCP identities and how they influence one another at the elementary level. In considering the communities that likely have access to computer science education (Marshall & Grooms, 2022), the authors are working toward creating more accessible and equitable experiences for students with marginalized identities to engage with Science, Technology, Engineering, and Mathematics (STEM). A goal of this work is providing opportunities for students who are underrepresented in STEM (Syed & Chemers, 2011) to participate in computer science programs and see themselves as mathematicians and computer programmers.

There is a dearth of research focused on how combining MCP learning experiences supports students as they generate and negotiate identities at a foundational point in their academic career (elementary and middle school). This after-school program provided students from grades 3-8 and college an opportunity to engage collaboratively (Lave & Wenger, 1991; Vásquez, 2003) with MCP content that is traditionally not connected in school-based programs and often not introduced until later grades. This study explores a game-based activity that students engaged with that supported academic and social identity growth in MCP. The current study is motivated by the following research questions:

1. How do moments of playful talk support students' identity construction related to mathematics and computer programming?
2. How do students articulate their academic and social identities when asked to reflect on their knowledge and liking of mathematics and computer programming?

Theoretical Frameworks and Literature Review

Situated within a sociocultural perspective (Vygotsky, 1978), this study focuses on how students interact and communicate with one another to build their social (Kim et al., 2018) and academic identities. Two main themes from sociocultural theory are apparent in this work - 1) the role of artifacts and tools and 2) social others in the learning process. Creating a learning environment that offers novices and newcomers new ways of participating with social others supports learning, as well as identity development (Nasir & Hand, 2006). The genesis for this study included a game-based activity (see Methods) that encouraged students to explore the relationship between MCP through collaboration and play. Through this activity, students engaged with authentic programming experiences based on algebraic thinking such as exploring use of variables, substitution, and algebraic operations. In observing and analyzing small moments of interaction, playful talk and a community of practice became lenses through which we explored the data related to various aspects of identity construction.

Playful Talk

Engaging in playful talk encourages students to negotiate and construct their social and academic identities. Lytra (2008) explained *playful talk* as a way to capture "a wide range of verbal activities and routines, including teasing, joking, humor, verbal play, parody, music making, and chanting that can emerge in learners' talk" (p. 185). Playful talk has been conceptualized in various ways. Waring (2013) explored how adults enrolled in an English as a Second Language (ESL) course engaged in playful talk as a means to explore their situational, relational, and personal identities. Sullivan and Wilson (2015) investigated how a group of sixth-grade students utilized playful talk to support collaboration in a science class. Tai and Wei (2021) studied how translanguaging and playful talk support teachers in reaching their pedagogical goals in an English Medium Instruction high school mathematics classroom. Less has explored the use of student-generated playful talk in after-school contexts where students are interacting with MCP concepts.

The authors seek to explore how playing a computer-based number guessing game, social interaction within one group of students, and playful talk influence how elementary students identify as mathematicians and computer programmers in an after-school environment. In their playful communication, students negotiated various facets of their identity, including their MCP identity and their social identity.

Community of Practice

Our approach is founded on a participatory, situated, and experiential engineering learning perspective (Berman, 1968; Dewey, 1902; Johri & Olds, 2011; Lave & Wenger, 1991), where the development of engineering and mathematical identities is parallel to a socialized process of learning (Esmonde, 2009; Litzinger et al., 2011; Martin, 2006). This approach supports a socialization process into mathematics and computer programming by engaging in practices and in a community where students do as, learn about, become part of, and belong to (Johri & Olds, 2011; Lave & Wenger, 1991; Wenger, 1998) the community. “Participation implies a negotiated process of learning that does not depend solely on individual cognitive structures and is heavily shaped by the shifting roles and relationships as newcomers get incorporated into a community of practice” (Nasir & Hand, 2006, p. 462). Within the activity, students experimented with different roles, which supported their academic growth and the negotiation of multiple identities.

Mathematics And Computer Programming Identity

Identity has been defined in many ways in educational contexts. Some of this work includes research related to identity in mathematics education (Aguirre et al., 2013; Darragh, 2016; Graven & Heyd-Metzuyanim, 2019), STEM and social identities (Kim et al., 2018), the relationship between identity and agency in mathematics classrooms (Boaler & Greeno, 2000), and identity as an “analytical tool for studying important issues of theory and practice in education” (Gee, 2000, p. 100). In agreement with Aguirre et al. (2013), “we define mathematics identity as the dispositions and deeply held beliefs that students develop about their ability to participate and perform effectively in mathematical contexts and to use mathematics in powerful ways across contexts of their lives” (p. 14). From this definition, we see the importance of context in how individuals view themselves as mathematicians. Adding on to this definition, we consider how opportunities to participate in an after-school program influence how students see themselves as mathematicians and computer programmers and how they identify (socially and academically) with STEM.

In the context of a study with students engaged in college-level computer science programs, scholars found, “a student’s depth and breadth of experience of computer science appears to be related to their ability to perceive relationships between math and computer science” (Sigurdson & Petersen, 2017, p. 114). When students *see the mathematics* in their computer programming experiences, it provides a better understanding of how the two disciplines interact. Additionally, social identity is important to consider as students build and negotiate their multiple identities. Kim and colleagues (2018) explain, “a STEM identity is a social based identity grounded in the extent to which individuals see themselves and are accepted as a member of a STEM discipline or field” (p. 3). Too often, students are pushed away from STEM courses and fields because of negative social experiences. At a pivotal point in their educational career, students should experience positive STEM spaces, while also engaging in moments that build upon their social identities. Opportunities that allow students, especially those with minoritized identities, to discover connections between mathematics and computer programming encourages them to build interrelated, rather than distinct, identities.

Methods

AOLME Context

The Advancing Out-of-School Learning in Mathematics and Engineering (AOLME) program centered on broadening the participation of Latinx students in STEM. One of the goals was to develop, implement, and revise an integrated bilingual (Spanish and English) mathematics and computer programming curriculum using authentic computing environments (i.e., Python as a programming language and the Raspberry Pi as a main platform). The AOLME curriculum consisted of two levels. Level 1 focused on middle school mathematics and the basics of computer programming using image and video processing (See Celedón-Pattichis et al., 2022; LópezLeiva et al., 2017); Level 2 included object oriented programming and robotics. The curriculum was implemented through an after-school program in an urban and a rural bilingual middle school. A second goal was to socialize students into STEM practices by including them as co-facilitators to co-teach the curriculum alongside an undergraduate student facilitator, typically from engineering, and by taking students on field trips that exposed them to the college-going process and STEM career pathways.

The AOLME Research Team included an interdisciplinary group of scholars from bilingual/mathematics education and electrical and computer engineering. This group developed the AOLME curriculum to provide access and opportunities for students to explore mathematics concepts through the use of computer programming. Students were encouraged to play as they explored algebraic concepts.

MCP Task - Number Guessing Game

Rather than require students to practice mathematical concepts through repetitive exercises and procedures, the goal of the Number Guessing Game was for students to explore algebraic operations within a computer program. This novel approach helped students become familiar with how they can use computer programming to accomplish a goal, while considering new ways to do mathematics. As they played, students analyzed the code in the game as a way to reinforce underlying mathematical concepts. The following operations were applied to the input ((2x+3)-3)/2 and students had to figure out how the program utilized inverse operations to guess the number they had input. After students explored and played with the Number Guessing Game, they had opportunities to write the code for this interactive game and have their friends try their newly developed program (Celedón-Pattichis et al., in press).

Research Design

The research design is a single intrinsic case study. The subjects were a special case in that the students who participated in the after-school program were typically middle school students; however, the participants highlighted in this study were upper elementary students. The group of participants included Martin, Victoria, Jenny, and Julia[1] (see Table 1) who attended an urban bilingual middle school with its student population being primarily Latinx. The approach was descriptive in that we illustrate how the group of students learned MCP together and how their identities evolved in relation to liking and knowing MCP after participating in the program during the 2019 spring semester. We aim to explore the evolution of their academic and social identities through instances of playful talk.

Table 1

Participant Information (All names are pseudonyms.)

Participant Information				
Name*	Julia	Jenny	Victoria	Martin
Grade	College	5th grade	4th grade	3rd grade
Role	Facilitator	Co-facilitator	Student	Student
Gender	Female	Female	Female	Male
Languages spoken	English, Mandarin, and Tibetan	English and Spanish	English and Spanish	English

Data Sources

Video Recorded Sessions

To explore how moments of playful talk supported students' identity construction related to mathematics and computer programming, we drew from twelve 90-minute video recorded sessions in which the participants learned the integrated curriculum collaboratively in a small group. In particular, we focused on Session 2 of the Level 1 curriculum, which included student interactions with the Number Guessing Game.

Student Exit Interviews and Attitude Scales

[1] All names are pseudonyms.

When the program concluded, participants engaged in student exit interviews which lasted approximately 30 minutes. The interviewers gave the option to students to conduct the interview in English or Spanish. As part of this interview, students also completed a self-rated scale that indicated how much students knew and liked mathematics and computer programming before and after they completed the after-school program. We used these data sources to answer the second research question. We triangulated this data source with MCP attitude scales administered to the students before and after the program. Four domains in this attitude scale included motivation, self-confidence, enjoyment, and usefulness of mathematics and computer programming.

Data Analysis

For the data analysis, we focused on questions related to students' feelings and knowledge of MCP and how these evolved since the beginning of the program. Additionally, we analyzed sessions in which the participants explored computer programming (Python) by playing a Number Guessing Game where the computer tried to "guess" the students' chosen number. Data was extracted from exit interviews and videotaped sessions of the participants engaging collaboratively with an activity that promoted MCP learning opportunities.

Results

In this section, we describe preliminary findings focusing on one student, Martin. Martin was the youngest participant in the program. When reflecting on his initial feelings about the program, he spoke about his age in comparison to his peers. "I feel really different, like I'm always the one that has to stand out…I don't see any other third grader." During this experience, Martin constructed and negotiated his social and academic identities and his current understanding of the relationship between MCP. By the end of the program, Martin explained that he was proud of himself for keeping up and collaborating with the rest of the students in his group.

When the students were first introduced to the Number Guessing Game, Martin quietly watched the other three students as they explored the game together. Once Victoria successfully completed one round of the game, Martin spoke up, asking "Wait, can you repeat it? I don't understand." It was not until Martin had the opportunity to engage in a new role (choosing the number and leading the game) that he began to verbally make sense of the MCP concepts. After having a chance to participate, he explained his understanding of how the computer knew his original number was five. "Wait, so then it subtracts thirteen and it divides that number by two. That's the alternative, that's how it gets it!" Victoria quickly affirms his thinking by stating, "Exactly!" In this moment, Martin's role and identity changed from one where he was unsure of how the game worked and observing his peers to one where he felt comfortable leading the group, knowing he had their support.

Playful Talk and Reflection

As they were playing the Number Guessing Game, students engaged in multiple instances of playful talk. Table 2 provides some examples that were extracted from the video data. These are important interactions in which the participants communicate with one another in playful ways that support meaning-making and positive STEM identities. When reflecting on his knowledge and enjoyment of MCP, Martin shared that they improved, and he attributes that to the opportunities he had to connect and work with his peers. This experience and the environment positively influenced his social and academic identities.

Table 2

Moments of Playful Talk from Small Group Video Data

Context	Example	Why is this important?
The facilitator, Julia, is writing numbers on her whiteboard and Martin comments on her handwriting.	**Martin:** [Points to Julia's whiteboard] Wait, what? How is that a five? [Laughs] I'm like, what? **Julia:** [Laughs] **Martin:** I'm just like, what? [Smiles] **Julia:** [Rewrites the number on her whiteboard] Five!	This moment of humor as Martin begins his first round of the game supports his transition into a new role within the group.
The students are trying to get the computer guessing game to figure out that their chosen number is zero.	**Victoria**: What's your number, Martin? **Martin**: Um, it's going to be zero. [Silly voice] **Victoria**: Ok, multiply by two. **Martin**: It's zero. [Laughs] **Jenny**: It's zero. **Victoria**: And add three. **Jenny**: That's three. **Martin**: It's three. [Silly voice] **Victoria**: So, obviously it's going to know our	The students are trying to trick the computer by trying the number zero. After the experience, Martin is convinced that the computer will always win the game.

	number is zero. **Martin**: What if it, wait... [Looks at computer screen] There's no number we can think of that it can't do! **Victoria**: Yeah, your number is zero.	
The students are trying to get the computer guessing game to figure out that their chosen number is one billion.	**Martin**: Two billion **Julia**: Two billion, yes. [Writes on whiteboard] It's two billion. And then, [Points to computer screen] **Martin:** [Points to Julia's whiteboard] Is that really the command for a billion? **Julia**: Um, yeah. It is. **Victoria**: It's just the word. Yeah. **Martin**: [laughs] **Victoria**: Instead of wasting your time [Pretends to write zeros with hand] putting nine zeroes. **Julia**: And then put two billion three. **Victoria**: Two billion and three. **Martin**: How would you do that? How would you do that? [Victoria types on keyboard, Julia writes on whiteboard.] **Martin and Victoria**: Two, comma, zero, zero, zero, comma, zero, zero, zero, comma, zero, zero, three. [Computer produces an error message] **Victoria**: What! **Julia**: What? **Martin**: Value error. [Laughs]	The students are trying a new number (one billion) and are not sure if it will work. Because of their use of playful talk, they move through moments of failure, realizing their mistake, and trying again as the Python programming language accepted numbers only without the commas.

	Julia: [Laughs] No, you don’t have to put this one. [Points to computer screen] **Victoria**: Oh. **Julia**: Now we are going to do it again. **Victoria**: Can’t we just put two billion and three? **Martin**: That’s a pretty easy number. **Julia**: [Scrolls up to the code] Because in the code you can, ok, do you want to try again? **Victoria**: Yeah! **Martin**: That’s a weird... [Laughs] **Julia**: But just, uh, don’t put the dots. **Martin**: Oh! That’s probably what it was. **Victoria**: I put the commas. **Julia**: Yeah, don’t put the commas. **Martin**: No commas, no commas.	
In the exit interview, Jenny was asked to explain the ratings she chose for her liking and knowledge of computer programming before and after the program.	**Jenny:** Well, before I didn’t really think computer programming could do anything for me. I just thought, hey I could just do whatever I want, I don’t need computer programming. But now I realize that there is a lot of things that come with computer programming and how important it is…like if you want to be a computer engineer, you have to have a college degree and you have to be, uh, you have to be fluent in what’s it called? Anaconda? **Interviewer:** Oh, the Python? **Jenny:** Yeah, Python. **Interviewer:** Yeah. [laughs] **Jenny:** I thought it was Anaconda. **Interviewer:** Yeah, yeah. Pretty close, right?	Even during a more formal context (1:1 interview), Jenny and the interviewer were able to engage in playful talk to make the space more comfortable and inviting.

When asked about the differences between mathematics in a school setting and in an after-school setting, Martin shared, “They are different because the math you’re doing at school is just like, you sit down with a piece of paper with a problem on it and they say solve it. Instead of putting you in a situation where you needed to know it…if you’re just doing it for the sake of knowing it, it doesn’t seem too helpful.” In connecting MCP, Martin said “I like math because it was the first thing I ever knew as a subject…then I learned about how mathematics ties to coding and it’s just really interesting to me. Mathematics is tied to practically anything.” In the weeks that Martin participated in this program, he had the opportunity to relate MCP topics, make sense of how they support one another, and negotiate and build upon his STEM and social identities.

During their exit interviews, Martin, Victoria, and Jenny were asked to rate their liking and knowledge of MCP on a self-reported scale ranging from 0 to 10 (see Table 3). Future work will include a more detailed analysis of the relationship between their enjoyment and knowledge of MCP and their comprehension of how the two domains are connected.

Table 3

Self-Reported Scales

(Using a scale of 1-10, participants were asked to share feelings about knowing and liking mathematics and computer programming during an exit interview. This table also includes an excerpt from the exit interview of each student related to this scale.)

Student Name	**Mathematics** (out of 10)		**Computer Programming** (out of 10)	
	Liking	**Knowing**	**Liking**	**Knowing**
Martin	4 → 6	5 → 8	7 → 9	2 → 6
Victoria	7 → 9	6 → 8	4 → 7	2 → 5
Jenny	4 → 9	1 → 9	5 → 8	3 → 8
Martin: “I really wanted to know how the computers work on the inside, how the robots take in messages and they output them…and then when I heard you’re making a video out of				

coding, that blew my mind and was just like, yeah! I wanna do this! [laughs]...It's just like now I get, I'm like connecting with people so now I know more people, and it's just like I don't have many friends at my school and it's cool."
Victoria: "[This program] has definitely taught me, no, teach me to like it. Especially the guessing game, where you take a number, you like multiply it by 2 and then you add 3 and we changed the program on that though. But I thought that was really good because a few of my favorite numbers are more than a billion. Unless we have to work with small numbers, my small number is a thousand."
Jenny: "Well, when I was in math, I didn't really like math that much, but I did it and I liked it because my friends would do math with me and stuff. And now I like it more because now I know that doing math is really important for binary and stuff. For even coding and other things too…. like doing binary code. Like turning the numbers to ones and zeros and stuff like that. And making hexadecimal numbers and making colors."

Discussion and Implications

Preliminary findings from this case study suggest that engaging with MCP concepts together and in informal spaces, such as an after-school program, are beneficial in providing students an opportunity to explore and negotiate various layers of their identities (Celedón-Pattichis et al., 2013, 2022; Esmonde, 2009; Litzinger et al., 2011; Martin, 2006). In particular, these informal spaces provide an opportunity for students to experiment with and explore roles (Lave & Wenger, 1991) they may not experience at school and use playful talk (Lytra, 2008) to establish themselves within a group. Teachers may see playful talk as an off-task behavior, prohibiting students from engaging in this form of communication in a typical school setting. Although it may be perceived as off-task, students are motivated to learn alongside each other when they are in a context where they feel supported and comfortable collaborating with one another. The preliminary data also shows that collaborative opportunities to joke and laugh with peers created a space in which participants felt comfortable trying something new, which influenced their liking and knowledge of MCP. Students should be provided more opportunities to engage with MCP concepts simultaneously and in playful and engaging ways. At a pivotal point in their educational career, students must have opportunities to experience positive STEM spaces, while also engaging in interactions that build up their social identities (Kim et al., 2018).

An implication of this work for school spaces includes providing elementary and middle school students opportunities to engage in playful talk and moments of play and humor as they engage with mathematics, computer programming, and other STEM disciplines. Additionally, elementary and middle school teachers can reframe how they teach mathematics, especially for those typically marginalized from STEM spaces (Marshall & Grooms, 2022; Syed & Chemers, 2011).

> We have to break from the notion that learning mathematics must be a linear and procedural endeavor mastered through rote practice and memorization. Instead, we must recognize and emphasize that interconnected concepts lead to stronger foundations in mathematics and stronger personal and mathematical identities. (TODOS, 2020, p. 3)

We add on to this idea by sharing that interconnected concepts must include additional STEM domains such as computer programming (Celedón-Pattichis, 2013). This study supports the notion that collaboration, exploring group roles, and playful talk positively influence social and academic identity construction (Lave & Wenger, 1991; Nasir & Hand, 2006). Next steps for this work include further analyzing other instances of playful talk within the small group.

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