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Session Title Multilingual and Multicultural Computer Science and Engineering Education

Session Type Paper

Presentation Date 4/15/2023

Presentation Location Chicago, IL

Descriptors Computers and Learning, Discourse Studies, Latino/a, or see Hispanic

Methodology Qualitative

Unit Division C - Learning and Instruction

DOI https://doi.org/10.3102/2009935

Bilingual Students Leading Bilingual Computational Thinking Collaborative Practices: A Rigorous Systemic Functional Linguistics Approach

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Abstract

Discourse used by facilitators is fundamental in providing culturally and linguistically diverse (CLD) students with opportunities to develop computational thinking through computer programming (CT-CP). Drawing on systemic functional linguistics (SFL) and situated learning, we illustrate how a group of CLD novice students of CT-CP, their language arts teacher (novice), and facilitator collaborated to program a digital video representation in Python. Data sources included video clips of group interactions, student-developed code, and student artifacts. Our findings indicate that 1) Encouraging the students to use Spanish and English freely in a motivational and collaborative environment can induce them to take on leading positions in CT-CP practices and develop CT-CP and 2) using SFL to analyze CT-CP educational contexts is a powerful resource.

Descriptors: Computational thinking, equity, systemic functional linguistics

Purpose

Advancing educational computational thinking research for all students involves a variety of disciplines and perspectives (Kfai et al., 2020). In the last two decades, educational researchers of related fields such as computer science, engineering and mathematics educational research have had a strong interest in supporting computational thinking education including how CT-CP can be defined, how it can be better taught and learned, and how to provide universal access to CT-CP for all students. To think in ways that enable all students to formulate problems and tasks in ways that computers can carry out, i.e., computational thinking, involves thinking processes and discourse which can take place bilingually. The purpose of this paper is to examine the discourse of a small group of culturally and linguistically diverse (CLD) students, their CT-CP facilitator's and language arts teacher's, to advance understanding of CT-CP educational contexts and how opportunities to learn and teach take place.

Several examples of bilingual, interdisciplinary, collaborative CT-CP practices will be presented where the students took leading positions in their collaborations with each other, and with their language arts teacher and facilitator.

Theoretical Framework

Central to Systemic Functional Linguistics (Halliday & Matthiessen, 2014) and situated learning is the relevance of the context in which participants make meaning and realize experiences and community practices through discourse (Wenger, 1998). In this study, we focus on the teaching and learning of computational thinking through computer programming (CT-CP) for the creation of digital videos, where mathematical abstractions play key roles, such as providing the formalisms that computers can process (Ben-Ari, 2012; Lecea Yanguas, 2022). This study took place in an after-school community of practice where we, alongside other members, strive to promote contexts where students (novices in CT-CP) participate from the start in CT-CP practices in Python (e.g., modeling, testing, debugging (Kong, 2019)). The approaches to teaching and learning we explore can broadly be referred to as 'participationist' (Sfard, 1998, 2008) and constitute a complementary approach, as opposed to exclusionary, to cognitive perspectives. Participationist approaches foreground student collaboration and talk, placing emphasis on student development of disciplinary discourses (Sfard, 2008).

We argue for the development and testing of pedagogies in situ, advocating for motivational lessons to ensure the active participation of all students irrespective of their prior experience in computing (Waite, 2017). We acknowledge and expect the resourceful ways bilingual students navigate CT-CP practices by means of their cultural and linguistic repertoires (Vogel et al., 2020). Our work follows that of Kafai and Resnick (1996) in that we target the interplay of learning CT-CP and design by engaging CLD students in contexts that they cherish to create their own videos generated through the identification and representation of their ideas and stories.

Within a learning cycle Design, Model, and Implement (DMI) (LópezLeiva et al., 2019) that students engage in as part of a content-and-language socialization process into CT-CP practices, we have identified bilingual indicators that mediate CT-CP practices, a variety of collaboration patterns among participants and student agency and leadership. We have identified instances where students engaged collaboratively in fundamental CT-CP practices bilingually, alternatively pairing up between them and with their language teacher (also a novice) and facilitator. By looking at this collaborative learning cycle, we aim to gain a deeper understanding of CT-CP educational practices and how bilinguals develop CT-CP discourse.

Methods

This study focuses on a small group of three middle schoolers, all novices to CT-CP practices, a facilitator and a language arts teacher who supported the group and was a novice in CT-CP as well. All of them were fluent Spanish-English bilinguals (Latin-American heritage) although with varying levels of proficiency. Most remarkably, the facilitator and one of the students could understand Spanish but rarely used it and, conversely, the language arts teacher could understand English but rarely used English. Our research questions were: 1) What role does linguistic identity play in students' CT-CP practices? 2) How is collaboration enacted in key CT-CP practices? 3) To what extent can the affordances of SFL perspectives and methods be useful in the study of CT-CP contexts?

The research context is an after-school program that introduces computer programming for the creation of digital images and videos with a bottom-up understanding starting from binary numbers to the pixel level to the color video level. The after-school program was implemented with middle school students in a rural setting using twelve sessions (1.5 hours each session). The bilingual (Spanish and English) curriculum prepares the students in seven lessons to design and implement digital image and video representations. The first six lessons include pencil-crayon-and-paper, modeling, and computer-based tasks and topics that include learning the basics of

Python, using coordinate systems to represent images and videos, and moving across number systems. The seventh lesson is a project: Designing, modeling with mathematics the students' original drawings (basically, the characters of the video), and implementing (programming) their images and videos. The students work in small groups of 3 to 5 students with a facilitator (undergraduate engineering student). In this case, a language arts teacher supported the group actively, mostly to help keep the students on task, while experiencing computer programming as part of their preparation for future educational endeavors.

Data Sources and Analysis

Similar to Lecea Yanguas (2022) and Celedón-Pattichis et al. (2022), this case study uses Systemic Functional Linguistics to analyze the discourse and practices employed by CLD students programming in Python, a popular computer programming language, to generate a digital video. Ultimately, the goal is to broaden our understanding on the teaching and learning of CT-CP, which have been reported to be difficult (Rappenning et al., 2016).

We combined SFL and case study perspectives and methods to analyze the last 3 of 12 sessions because we were interested in the collaborative dynamics that took place during the student creation of the video in Python. A thorough explanation of our analysis design and rationale is detailed in the full version of the paper. Data sources included 4.5 hours of videotaped group interactions with the corresponding computer screen recording that captured Python code and digital images and video as was being created by the students. Data sources also included transcriptions of all group interactions, curriculum guidelines, and student artifacts (drawings and digital images). Furthermore, we analyzed the videotaped (each approximately 20 minutes) interviews and related transcripts of all participants: the 3 bilingual students (Herminio, Michael and Juan), the facilitator (Teresa) and the language arts teacher (Yanet). Additionally, we analyzed the transcriptions of all 12 sessions to identify relevant Spanish keywords that the students used.

We selected episodes for SFL-case study analysis from the three sessions when the students created their video. Our selection criteria included that Spanish was used and that key CT-CP practices were involved (Kong, 2019). We used SFL-based codes such as processes (verbs) and agents (nouns and pronouns) which we categorized according to whether they belonged to the world of CT-CP, mathematics, image and video processing or the students' personal and imaginative worlds. Then, themes were identified and further triangulated with other data (interviews, and curriculum guides) through a comparative and contrastive process (Tracy, 2019).

Findings

Our findings indicate that providing CLD students with CT-CP educational contexts where they are encouraged and supported to make meaning of their practices bilingually (See Table 1 and Table 2) and collaboratively can result in productive student-student and student-(novice in CT-CP) teacher collaborations where the students take the lead in CT-CP practices and develop computational thinking. Further research can illuminate the extent to which novice teachers can develop CT-CP in these collaborations.

We provide examples of the students using Spanish and English while displaying their agency in modeling, testing and debugging collaborative practices where they alternatively paired up with another student, the teacher and the facilitator. Spanish was also constitutive of the tangible products of their work, that is, their Python code and digital video, and had significant presence across the whole curricular activity.

In the following excerpt, Michael (M) used Spanish to explain to the language arts teacher (T) what he was programming, the head of a wither skeleton, and also that he could simply run it to test the result of the Python program.

M: Ahorita esto es solo el código de mi,
mira solo esto es el código de esto.
T: ¿Solamente de la cabeza? (just of the head?)
M: Mira de esta de acá, de la cabeza. (Look at this one, of the head.)
[pointing to the head on his crayon-drawn design on a paper grid]
T: Wow!
M: De la cabeza (Of the head)
T: Entonces, ¿tienes que poner todo? (Then you have to put it all?)
M: Mhm,
eso es apenitas el pequeño código, (that is only the little code)
no estamos ni llegar al cuerpo todavía (we have not started the body yet)
T: Oh, God,
M: Y si quieres ver si está bien (And if you want to test if it's okay, le das a run (You click run).

Importantly, the CT-CP procedure that Teresa facilitated (Design-model-implement) to create the video allowed instant testing (See Figure 1). As the students programmed their prototypes in Python code, they would execute the program to test it and evaluate its result. Consistently, the students called their tests out whenever they performed them. They or the facilitator would produce short proposals such as: "run it," "F5," "watch," "look," or "See the magic happen" as Michael used to say. Clicking F5 would trigger participants' cheering comments if the results were satisfactory—for instance, the facilitator's pervasive, "there you go"—or assistance if needed. Below, Figure 1 shows the prototype of the wither skeleton and how Michael progressed through the programming process.

Testing the code involved the evaluation of the outcome produced, that is, the image output that the students' Python code produced. The facilitator encouraged the students to debug their code visually by running their code as they worked on their video representations (just with a click of F5). To encourage code testing, the facilitator would say "click on the code" or "go back to your code", which typically triggered comparison between the code and the image it had produced or the analysis of the error that had impeded its production. Figure 1 shows the wither skeleton under development as Michael was coding it. When Michael pressed F5 to "see the magic", displayed at the lower part of Figure 1, the computer system returned a crooked arm (note the left arm of the character with an extra pixel). The students were not satisfied with the outcome; thus, they modified the code and fixed it. "You messed up right there," Juan said; to which Michael responded: "I'm curing him." Michael's use of the pronoun I in this testing episode is a discursive indicator of his agency in this moment of practice and of CT-CP development as will be explained in detail in the paper.

As illustrated in Lecea Yanguas (2022), the students were developing CT-CP. They were learning to evaluate the results executed by the computer, analyze the Python program they were developing and undesired results or errors. As Michael had explained in Spanish to the teacher: "Y si quieres ver si está bien (And if you want to test if it's okay) || le das a run (You click on run).

Significance

This study contributes to the field of CT-CP educational research by providing evidence that CLD students can participate successfully and take on leading roles in CT-CP interdisciplinary practices that promote collaboration and student use of their linguistic repertoire (Spanish and English). Also, it adds to the emergent body of research targeting broadening participation of underrepresented groups in CS and CT-CP (e.g., Goode et al., 2020). Student willingness to take on leading positions in their collaboration with (novice) teachers is relevant given the difficulties encountered in schools to teach CT-CP (LópezLeiva et al., 2022). In addition, our study contributes to broadening research lenses by incorporating the application of SFL tools and perspectives to the study of CT-CP educational research.

Acknowledgements

This research was supported by the National Science Foundation (NSF) Awards 1613637 and 1949230. Opinions, findings, and recommendations expressed are those of the authors and do not necessarily reflect those of the funding agency.

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Figure 1

Wither Skeleton Prototype and Two Results Obtained After Testing the Python Program Under Development

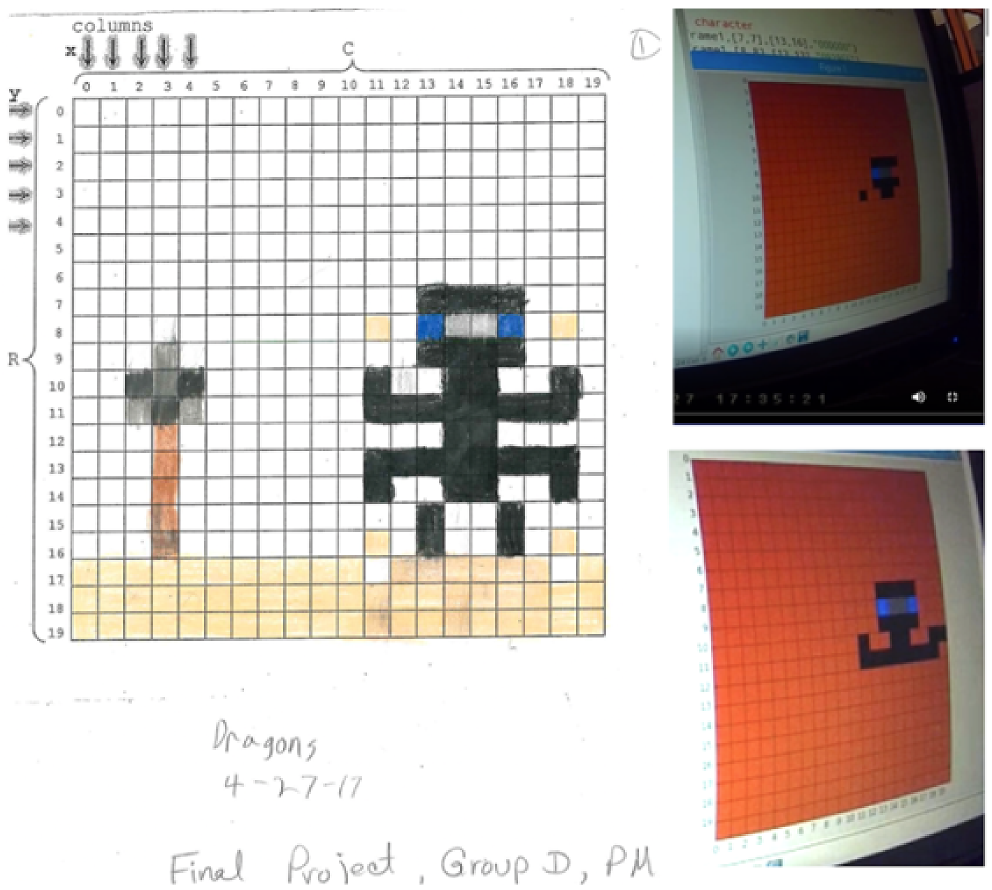

Table 1

Examples of Bilingual Processes in Their Original Worlds

	The students' personal and imaginative world	The world of computer programming	The world of mathematics	The world of image/ video-processing
Processes (verbs)	squish, digest, disappear, get bigger, make bigger	code, test, *probar* (test) run, *correr* (run), *cambiar* (change), change, debug	add, multiply, convert, calculate	draw, make bigger, play, *moverse* (move), move

Table 2

Examples of Bilingual and Non-Human (Discursive) Agents *in Their Original Worlds*

	The students' personal and imaginative world	The world of computer programming	The world of mathematics	The world of image/ video-processing
Agents (nouns and pronouns)	you, we, tú (you), nosotros (we, us) asteroid, dust, land, sun, wither skeleton, shovel, fin (end), end, cereal, mom, *cabeza* (head), head, *árboles* (trees), trees, *color* (color), color, step, "13 to 15", "11, 11"	you, we, tú (you), nosotros (we, us), ayuda (help), help, variable, function, algorithm, integer, float, string *paréntesis* (parenthesis), parenthesis, the code, computadora (computer), computer, im_show, im_fill, frame_list, fps *color* (color), color	you, we, tú (you), nosotros (we, us) variable, integer, algorithm, function, parenthesis, coordinate, axis, number, number, *color* (color), color, step	you, we, tú (you), nosotros (we, us) crayon, pencil pixel, frame, *color* (color), color