Paper Title "¿Qué Funciona?" Translanguaging, Epistemic Agency, and Storytelling for the Authoring of Ideas in Computer Science

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“¿Qué Funciona?”: Translanguaging, Epistemic Agency, and Idea Crafting for Computer Programming

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Abstract

Understanding how students compose CSM ideas is essential for engagement, the development of content knowledge, and a robust STEM identity. This case study focuses on the linguistic and pedagogical transformations during computer science and mathematics learning. We document these transformations accompanying idea formation and authorship to identify three essential findings: 1) Translanguaging provides a pedagogical tool for epistemic generativity, 2) Idea-crafting and pedagogical modeling, and 3) The concept of self-pedagogy. Students use translanguaging, exercising epistemic agency to order their learning experience and providing opportunities to reposition themselves and others. In one learning sequence, Joaquin, a student co-facilitator, uses space-time marking to help manage/organize current activity with past experience. These links establish an episodic account of learning that is managed, organized, and referenced as part of a larger narrative. In doing so, he authors a model that provides a substantive connection to content for his peers.

1. Introduction

As the world continues its tilt towards increasing virtualization, the boundaries between us and computers within rapidly evolving digital spaces continue to dissolve. Our experiences will remain at the forefront, favoring those who would have benefited from opportunities to enhance their appreciation and knowledge of computers, programming, and practice. It is vital to anticipate and contend with the present and future challenges that hobble our capacity to provide robust and sustaining opportunities to participate in and leverage technology to discover, create, and enrich our lives and the lives of others. Within the context of education, this holds considerable bearing. In this spirit, we have fostered many educational initiatives and frameworks to promote computer science and mathematics (CSM), for example, International Society for Technology in Education, Computer Science Teachers Association K-12, AP Computer Science Principles/Computer Science A, Expanding Computing Education Pathways, and to some degree, the Next Generation Science Standards. Yet, despite recent efforts to increase access, participation in computer science remains limited (College Board, 2020; NCES, 2022). This is especially true for women, rural communities, and urban schools with culturally and linguistically diverse students (Google Inc. & Gallup Inc, 2016; NCSES, 2023; Pew Research Center, 2021; Code.org Advocacy Coalition & CSTA, 2021). Although many of these reports note considerable progress through various positive indicators, for example, the number of schools offering computer science or student enrollment and performance in AP CSP, these recent gains vary significantly between states and across regions. Schools within Indigenous, Black, and Latina/o communities are less likely to offer computer science, and for those that do, their students are less likely to enroll. It is, therefore, necessary to explore how we can help and support these communities strategically, logistically, and politically as they strive to provide meaningful CSM experiences to their students. Thus, the following initial research question directed this study: How do linguistic and pedagogical-link making practices transform as students craft ideas during CSM learning?

2. Conceptual Framework

2.1. *Perspective on learning*

The framework for this project (Table 1) was inspired by the work of Bruner (1987a, 1987b, 1991), and adopts a narrative-constructivist perspective. This view centralizes "world making" as a premise for cognition. According to Bruner, narrative is "a mental model whose defining property is its unique pattern of events over time" (p. 6). Narrative is meaning-making through the ordering of experience. The science disciplines, physics, chemistry, biology, and computer science are "ways of worldmaking". Learning is an interactive process between an epistemic agent and their environment, resulting from the operative development of all forms of knowledge acquisition and their inexorable transformations across time (Piaget et al., 1988). This genetic epistemological process is a concerted dynamic of assimilation and accommodation, corresponding to a represented and representing world (Vygotsky, 1962, 1978). As students engage in STEM learning, they negotiate meaning by ordering experience while aligning knowledge with the physical world.

2.2. *The role of language*

Language is a tool for ordering experience (Bruner, 1987a). Translanguaging is the leveraging of languaging features to help us make sense of the world, and then to express that significance in a meaningful way (Garcia & Wei, 2014). Language is an emergent feature of communities (Kim et al., 2021). As languagers, we draw from a unified set of experientially developed linguistic features. These features include other aspects of language, such as semiotics and gestures (Kusters et al., 2017; Otheguy, 2015). We tend to differentiate the world into actions and things, regardless if we draw from one language or another. These distinctions are ordered hierarchically to encapsulate meaning.

2.3. *Authorship and pedagogy*

Pedagogical link-making (Figure 2) is the connecting of ideas throughout the sustained meaning-making interactions of a learning experience. This pedagogical approach equips teachers with a practical tool for the nuanced understanding of science communicative practices and student prior knowledge. By examining conceptual-links during STEM learning, it is possible to evaluate the authorship of ideas by considering how, where, and by whom a link is made (Lehesvuori & Ametller, 2021). Idea authorship can be traced throughout a dialogic exchange and the creation of learning artifacts (e.g., models, diagrams, notes). When combined with a narrative-constructivist and translanguaging framework, it provides a foundation for understanding and supporting the authorship of student ideas.

3. Methods

This qualitative research study explores how learners author ideas and the self as they construct CSM content. It was imperative to examine this negotiation holistically as an emergent and iterative feature of CSM learning. Thus, qualitative research methodologies are aptly selected for their robust capacity to describe, contend with, and explain phenomena as they occur during lived experiences (Patton, 2001).

3.1. *AOLME Context and Researcher Positionality*

The Advancing Out-of-school Learning in Mathematics and Engineering (AOLME) program integrates students' cultural and linguistic knowledge with the work and practice of computer engineers and bilingual/mathematics educators to broaden the participation of underrepresented students, including Latinx, in authentic STEM practices (Celedón-Pattichis et al., 2013, 2022; LópezLeiva et al., 2022). Within AOLME, students learned computer programming and mathematical concepts in a bilingual, after-school setting (LopezLeiva et al., 2017, 2019, 2022) through two levels of the AOLME curriculum. Level 1 focused on learning mathematics concepts and the foundations of computer programming using video and image processing; Level 2 covered object oriented programming and robotics. We used Python, a text-based computer programming language, and the Raspberry Pi as a main platform.

The AOLME Research Team consists of a group of interdisciplinary scholars from bilingual/STEM education and electrical and computer engineering. Sylvia, Carlos, Esteban, and Irán are Spanish native speakers; they supported the analysis of the translanguaging practices represented in this work. Sylvia and Carlos also collaborated with other team members to design the activities in Spanish for Levels 1 and 2 of the AOLME curriculum. Hannah, Amy, Marios and all team members are committed to advancing Latinx STEM education drawing from an equity lens and using an asset-based approach that honors Latinx students' languages and cultures as resources to make meaning of mathematics and computer programming.

3.2. *Setting, Participants, and Research Design*

The research study employed data collected from an afterschool program using the AOLME curriculum at a bilingual middle school (population < 500) within a rural school district in the Southwest where the English language learner student population was 42% (APS Dashboard, 2022). The student population of the school was approximately 91% Latina/o. All student participants were eligible for free or reduced-price lunch.

The setting and participants for this single intrinsic case (Yin, 2017) were selected using purposeful sampling techniques (Patton, 2015) based on school setting, working group makeup, interactions, and facilitator/co-facilitator qualities. This study follows the CSM learning experiences of a small working group as part of their participation in the AOLME program at a rural school. The working group consisted of three members, an undergraduate facilitator, a student co-facilitator, and a level-one learner. A brief description of each participant can be found in Table 2. Hereafter, the participants will be referred to by their corresponding pseudonyms: Ngon (Facilitator), Joaquin (Co-facilitator), and Jacob (Student).

3.3. *Data Sources*

3.3.1. *Videos.* Videos were selected from a digital library containing over 1200 hours of content documenting Latina/o students' experiences learning CSM using the AOLME curriculum in both urban and rural schools. From this library, a data set was constructed by selecting video sessions documenting the aforementioned working group. The data set consisted of twelve 1.5-hour learning sessions that were subdivided into 20-minute videos. During each session, students worked collaboratively in groups moderated by a facilitator and co-facilitator. This study presents findings from the first working sessions. Videos were selected for the following criteria:

1) Group dynamics - the group dynamics between the facilitator, co-facilitator, and students were of interest due to their particular emergent pedagogical interactions and translanguaging moments. The first content oriented sessions were ideal to understand the progression of the group dynamics established by the facilitator/co-facilitator.
2) Nature of the orienting concept - the first activities were fascinating for several reasons. First, the topic is deceptively simple, but worthy of extensive consideration due to its positioning within the established AOLME curriculum and its capacity to orient the learner within the broader knowledgescape. The initial activities guide the learners as they attempt to conceptualize the fundamental hierarchical structure of a computational system (virtual/physical aspects of a Raspberry Pi) and how to navigate it.
3) Moments of translanguaging - we focus on moments of translanguaging as an important component in our attempt to understand the linguistic features associated with the learning experience and how it is structured by learners.

3.3.2. *Artifacts*. Artifacts were used as a secondary data source, providing structural context for each learning space. Examples of artifacts included instructional cards, the programming environment, visual aids/imagery, and student work.

3.4. *Analytical Approach*

Data were evaluated and analyzed for evidence of the implicit or explicit use of pedagogical links and the linguistic features composing the sustained learning interaction to explore student crafting of ideas during the CSM learning experience. After preliminary viewings, content logs captured our initial impressions. Video data were transcribed, timestamped, and checked for accuracy. Transcripts generated during this initial round focused solely on speech. A second round of transcription identified the non-verbal aspects of each interaction (Domínguez, 2005). Keywords and developing codes attempt to trace translanguaging moments and the use of pedagogical links. We generated preliminary findings by comparing analytic memos, artifact processing, and open coding. Emergent thematic elements within selected episodes were further categorized and augmented through iterative analysis (Saldaña, 2021).

This study presented an opportunity for the researchers to listen and learn from the experiences of novice programmers within a bilingual context. Our analysis yielded three essential findings, guided by our interest in student authorship of ideas and the transformations in language and pedagogy accompanying idea formation. What materialized was ordered and will be thematically presented and discussed accordingly. First, our findings will be presented holistically using the following theme: students use language and pedagogical links to construct content knowledge through the ordering of experience. We will then address the three essential findings:1) Translanguaging provides a pedagogical tool for epistemic generativity, 2) Idea-crafting and pedagogical modeling, and 3) The concept of self-pedagogy.

4. Findings

4.1. *Students use language and pedagogical links to construct content knowledge through the ordering of experience*

Preliminary findings suggest that student language and pedagogical practices transform during content knowledge construction and idea formation as students use language to initiate and guide a search for meanings amidst a spectrum of possible meanings (Bruner, 1986). The following learning sequence attempts to highlight the use of language and pedagogical links to construct content knowledge through the ordering experience. In an attempt to maintain phenomenological fidelity and transparency, the interaction is presented and discussed holistically.

The learning sequence presented (Table 3) highlights the interactions between bilingual learners of varying experiences as they explore their understanding of a Raspberry Pi (computer system). Ngon, the facilitator, initiates the learning sequence by repositioning the Raspberry Pi towards the center of the learning space. Nothing is spoken in the immediate moments before or directly after this act. This act is significant in that it attempts to facilitate the orientation of the learning experience by directing attention toward the phenomena of interest to support knowledge building by suggesting the device as a learning tool. Implicit in this action is the pedagogical intent of a phenomena-first approach. Because the instructional card for this unit contains a labeled diagram (Figure 2) of the device and its components, the students directed their attention toward either resource during the activity.

Ultimately, there is an alignment of intent between Ngon and Joaquin, as he uses the device as part of his opening instruction. Joaquin begins his instruction by introducing his idea of computer components, starting at the micro-USB port. We find this particularly intriguing because there are no explicit instructions in the instructional card to prompt the discussion - he could have reasonably chosen any of the other components as a starting point. The decision to start with "power" was made solely by Joaquin based on his previous experience learning and working with a Raspberry Pi. His orienting question, "..on the Raspberry Pi, where's the power?" takes an inquiry-based approach, prompting Jacob to make a link to the phenomena, the Raspberry Pi (to which he gestures). Moreover, Joaquin's decision to introduce the concept of a Raspberry Pi from the port used to power the device serves as a continuity anchor from which ideas and experiences can be organized and built. Throughout the sequence, Joaquin intently manages his attention between Jacob, the device, and the instructional card.

As a Level-1 learner, Jacob's uncertainty is evident, embodied in his expression and gesture before his response, "*En todo*." On Turn 4, several exciting aspects occur. After responding, "*No*," Joaquin pauses intentionally before responding, "*Mira*." Reciprocity emerges from this translanguaging moment. In his uncertainty, Jacob moved towards Spanish, to the familiar, to express his apprehension. Joaquin exercises epistemic agency and reciprocates, mobilizing his linguistic repertoire to effectively extend this familiarity to promote the development of conceptual understanding:"What's the Power? *¿Qué conecta eso que funciona?*". This translanguaging act of epistemic agency creates a pedagogical link to elicit emotional engagement. Further, it allows them to reposition themselves and others with what they intend to learn. Moment-to-moment interactions like these hold considerable cumulative bearing over students' learning trajectories and success (Krause et al., 2019).

Joaquin actively contributes to the ordering of the learning experience by interweaving existing knowledge with new ideas into a culturally informed filigree (Vygotsky et al., 1987). Turns 6 and 8 (Table 3) document how Joaquin creates a pedagogical link to promote the continuity of shared experience. The ideas presented become part of an ongoing conversation unfolding across time. These links establish an episodic account of learning that is manageable, organized, and referenced as part of a larger narrative. Joaquin is attempting to create a shared account, or story, of their learning activities within the world of computer science. These links are nested within the computational world of thing/object and action - the Raspberry Pi and "*funcionar*" ("to turn on"). Space-time marking helps them manage/organize current activities with experience. When Joaquin states, "We did this last time" and "This is a review, Jacob," he is creating a model for the redescription of the world, which provides a substantive connection to the content. In doing so, Joaquin extends another appeal for Jacob to reposition himself with the subject matter by elevating him as capable of identifying the power component of the Raspberry Pi.

4.2. *Translanguaging provides a pedagogical tool for epistemic generativity*

Translanguaging moments similar to those presented in Learning Sequence 1 occur throughout the data set. While it is impossible to predict when such moments will happen, we have observed that students use language features to contend with uncertainty, revealing the manifold possibilities that unfold during knowledge construction. Turns 1 and 10-13 in Learning Sequence 2 (Table 4) highlight the translanguaging moments surrounding Joaquin's and Jacob's endeavor to identify and make sense of the USB and ethernet controllers (Fig 2). These components bridge multiple devices and moderate their operation. These are not the most prominent components of a Raspberry Pi and can easily be confused based on their form. In turn 3, Joaquin notes their similar appearance. In the translingual context, students draw from their wealth of knowledge (Vélez-Ibáñez & Greenberg, 1992) during sense-making. These familial schemas inform, support, and enrich learning. Joaquin begins this learning sequence by rooting the introduced concept with previous experience. Translanguaging infuses this incipient pedagogical act with familiarity as a continuance of their computer programming journey.

4.3. *Idea-crafting and Pedagogical Modeling*

Idea crafting is an exercise in epistemic agency in which students shape the knowledge building-work that influences the learning trajectory (Cherbow & McNeill, 2022). Co-facilitators often generate pedagogical models to facilitate conceptual understanding. Pedagogical models are representations that promote link-making through various modalities. These differ in purpose and scope from formal scientific models. Pedagogical models often capture foundational features or the essence of a concept, serving as a platform for the development of deep learning. Joaquin authored several pedagogical models to help support Jacob's learning. These were particularly important when confronting concepts at higher levels of abstraction. As an example, we will examine some of the pedagogical models generated while learning the virtual structure of computational systems and how to navigate them using Linux commands. Table 5 overviews the Linux commands and the AOLME programming environment. We have also provided the instructional card for reference (Fig 3). Joaquin and Jacob had to familiarize themselves with how Raspberry Pi structures information hierarchically to navigate the virtual space.

Excerpt 1

1 Ngon: What is the difference between folder and file?

2 Jacob: What contains the information? (Looking at Ngon with uncertainty)

3 Ngon: In real life, what’s the difference between folder and file? (She grabs a nearby folder.)

4 Joaquin: The files you put in the folder and the folder holds them.
5 Jacob: The files are…information. They go in folders? (Ngon pulls a file.)

The group works collaboratively to develop a pedagogical model for understanding the computational distinction between files and folders. Jacob soon discovers that the difference between fire and folder gets complicated when using the terminal to enter commands instead of interacting with the GUI (Graphics User Interface). The group continues to reference this model throughout the session. The preliminary version of the model only included physical ways of representing files and folders using the instructional materials made available to the group. These instructional materials organize and store the AOLME curriculum, such as instructional cards, handouts, surveys, and a labeled cardboard box. The materials do not discuss pedagogical modeling or the use of instructional cards and folders as representations for the lesson. The group's resourcefulness allowed them to employ these resources in a moment of spontaneous pedagogy. Joaquin uses the box to represent a directory in another moment of spontaneous pedagogy after noticing Jacob's struggle with the command PWD (Table 6).

Excerpt 2
1 Joaquin: So, if you type that [*PWD*], what does it [computer output] tell you?
2 Jacob: It tells me…that I am home? (Jacob laughs nervously.)
3 Joaquin: Okay…(Looking around for something before pointing to a box labeled "C".)
4 Joaquin: Look right here, what is the name on the box?
5 Jacob: Champions! Err, C!
6 Joaquin: C, right? So if you type PWD it's going to show you C. Why? Because you are there. (Joaquin points at the letter C and taps it for emphasis.)

Joaquin crafted ideas during moments of instruction to help teach concepts that Jacob struggled to grasp. This model would allow them to learn all four basic commands while applying them in a practical way. The pedagogical links made using pedagogical models often bridge what we are trying to learn with grounded experience by temporarily moving down a level of abstraction.

4.4. *Self-pedagogy*

One of the most intriguing aspects of this study was the opportunity to observe how student thinking transforms over time. While tracing the pedagogical links formed throughout these sessions, some interesting patterns emerged. We expected that many of the pedagogical links authored would emanate from the facilitator before being adopted by the co-facilitator. Unsurprisingly, we captured some of these moments, which we have presented in Learning Sequence 1 and Excerpt 1. Their inclusion acknowledges previous work done with link-making (Lehesvuori & Ametller, 2021; Scott et al., 2011), despite our primary focus being the students, particularly the co-facilitator. However, this working group was selected primarily because of the hands-off approach of the facilitator. In doing so, she allows the students to direct their learning and, to some degree, order their experience. We have demonstrated how Joaquin authored many pedagogical links to support his and Jacob's learning (see turns 2, 4, 6, 8, 10, 12, and 14 in Table 2). What is more, Joaquin employed several pedagogical techniques, which appeared to manifest as they engaged in content knowledge construction. As we examined the linguistic features that Joaquin and Jacob used as they expressed ideas, there is a discernible difference in the degree to which those ideas are mobilized for externalization. Many of Jacob's responses (for example turn 8, Table 3) resemble forms of inner speech (Vygotsky, 1934). Although he may be responding to others, they help him work through an idea or concept in a self-regulatory way (Clowes, 2007). Over time, his language transforms, reflecting greater external expression. Excerpts 3 and 4 attempt to capture this change.

Excerpt 3

1 Joaquin: (Reading the instructional card.) Try these commands and discuss what happens.

2 Jacob: What commands?

1 Joaquin: These ones. Try PWD. (Looking at the instructional card, then to Jacob.)

2 Jacob: (He starts to type hesitantly using the keyboard)

3 Joaquin: Wait. Do you know what is PWD? She explained it. (He gestures towards Ngon.)

4 Ngon: Well, to you [Joaquin] not to him.

5 Jacob: I know but…(Speaking with uncertainty.)

6 Joaquin: But he was hearing, right?

7 Jacob: (Taps his hand anxiously.) It’s to….make copies?

Excerpt 4

1 Joaquin: How do you know where you are?

2 Jacob: PWD. (Ngon smiles with joy as she throws her hands up before clapping them.)

3 Ngon: Yeah so what is that? What is PWD?

4 Jacob: (Without hesitation) It's a command.

5 Joaquin: There, you see. It's easy.

The transformation between Excerpts 3 and 4 occurs within 40 minutes. At the time in the lesson depicted by Excerpt 3, Jacob's uncertainty becomes a mantle. It is reflected in his posture and the way that he holds his keyboard and types in commands. He does not type unless Joaquin explicitly tells him. As he slowly develops his skills through practice and trying to type commands, his demeanor changes. Jacob grows in confidence in both speech and action. Over the 90-minute lesson, with Joaquin's support, Jacob can navigate the file system and use the commands he has learned to rename, create, and delete files within specified locations.

Joaquin's ideas are pedagogically oriented. That is they can be externalized to support learning in various ways. When he expresses his understanding of a concept, he can present that idea in multiple ways. The way in which an idea is presented can change the order of experience during a learning interaction. We agree with Bruner that students construct meaning through the ordering of experience, which begs the question, for whom is this experience ordered -for ourselves or others? Pedagogical links are used to connect existing knowledge with new ideas (Scott et al., 2011) as knowledge is structured hierarchically. From the constructivist perspective, we generally refer to this structural nexus as a schema. To what extent are schemas structured pedagogically and what would that mean for learning? During our analysis, we found it helpful to distinguish between two types of pedagogy, self and external. Knowledge structured in ways that we can readily externalize to support the learning of others constitutes external pedagogy. Self-pedagogy, on the other hand, is constituted by how we structure knowledge to support the development of our understanding. As our knowledge within a specific domain deepens, the knowledge is structured pedagogically for externalization.

5. Discussion and Implications

We explored the transformations in linguistic and pedagogical link-making practices as students craft ideas during CSM learning. This case study highlights the transformative dynamic between students and content knowledge construction. As students construct content knowledge, they simultaneously and inexorably construct the self. This entanglement that exists between worldmaking and self-making is vital for robust understandings of STEM identity, science participation (Gutiérrez & Rogoff, 2003), epistemic agency/epistemic heterogeneity (Warren et al., 2020), and the importance of STEM language and discourse (Lemmi et al., 2019).

The construction of formal models is standard scientific practice. Models are functional visual representations of phenomena used to facilitate conceptualization, problem-solving, or scientific forecasting (Clement & ReaRamirez, 2008; Justi & Gilbert, 2002; Schwarz et al., 2009). The construction of formal models is viewed as an essential practice in STEM education and has been extensively studied (Chittleborough & Treagust, 2009; Chiu & Lin, 2019). Models created to teach STEM concepts are often restricted to formal pedagogy and are associated with the development of professional teachers. However, we have shown that student co-facilitators create models to help support student learning of CSM concepts. Many co-facilitators create pedagogical models during the moments of dynamic instruction. In the case of Joaquin, he exercised his creative freedom in the learning space established by his facilitator Ngon. In other groups, the facilitator was more involved with the instruction and became the sole source for pedagogical models. This speaks to the importance of creating learning spaces that allow opportunities for students to develop and pursue science ideas and facilitate the flourishing of emergent science identities. However, prevalent methods of STEM instruction defer to the memetic practice of science, particularly those forming the core of canonical science. Limited vision and conceptual rigidity during curricular enactment constrict opportunities for student expressions of epistemic agency.

The quintessence of STEM education is the spark - that moment of candid appreciation for the largest or smallest things as we make sense of the world (worldmaking), and our place in it (self making). Student experience is central to STEM learning. This raises important questions about what we can do to design for the authentic manifestation of such experiences (Windschitl & Calabrese, 2016). The narrative perspective of learning adopts a meaning-first approach and stresses the ordering of experience. Every lesson, concept, and idea becomes a story that serves as vehicles for instructional activities, providing a cohesive experience driving inquiry, idea formulation, and elaboration. These are forms of external pedagogies. As ideas develop, they are formed in ways that can be externalized to convey meaning and support learning. Understanding Joaquin's development as a co-facilitator requires an understanding of the reciprocal nature of the interaction between content knowledge and the self. In this regard, we have found the term self-pedagogy to be useful. This concept will be explored in a subsequent study.

Table 1

Facilitator, Co-facilitator, and Student Characteristics

Facilitator Characteristics	Co-facilitator Characteristics	Student Characteristics
Ngon is a senior undergraduate student fluent in Vietnamese and English.	Joaquin is a 7th grader who loves to play soccer. His favorite subject is science. He regards himself as a beginner-intermediate in both Spanish and English.	Jacob is a 7th grader who loves music. His favorite subject is science. He considers himself bilingual. His linguistic repertoire includes Spanish and English.

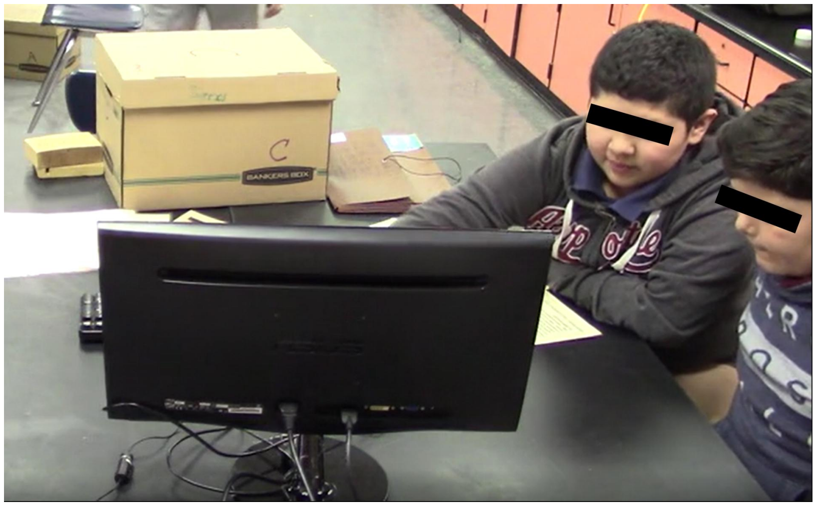
Table 2

Concept and Aspect of Interest

	Concept	Aspect of Interest
Bruner, 1986,1987	Ordering of ideas	The ordering of base knowledge quanta during idea crafting. We are particularly interested in its occurrence during the moments of learning/instruction.
Scott et al., 2011	Pedagogical-links	The nature and intent of the pedagogical-link, and by whom the link was created. Who or what was positioned as the "source of knowledge"?
Garcia & Wei, 2014; Mortimer & Scott, 2003	Linguistic features	The ways in which ideas and links are expressed, or meaning is encapsulated.

Table 3

Translanguaging: Agentic Moment & Pedagogical Tool - Instance 1		
Turn	**Act**	**Pedg. Link/Source**
1	NGON [Grabs the Raspberry Pi and places it in the middle of the table.] 	Knowledge building/Facilitator

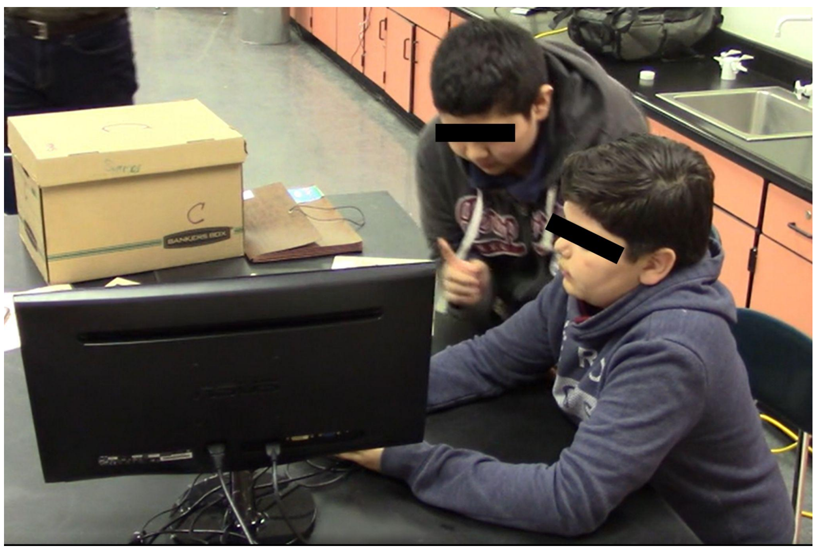
2	**JOAQUIN** Where’s the… [Pointing towards the Raspberry Pi, alternating his gaze between the device and Jacob]  on here on the Raspberry Pi, where’s the power?	Knowledge building & Continuity /Co-facilitator
3	JACOB [Shrugging as he looks at the device before throwing up his hands] mmMMmm (hums “I don’t know”). *En todo*. [His hands hit flat upon the table.]	

4	**JOAQUIN** [Looking towards the Raspberry Pi] *No*. [Looks down at the instructional unit card] *Mira*. Power *Mic(ro)* to USB. [Looks towards Jacob.] What's the Power? [Looks at the Raspberry Pi, pointing towards it and motioning to outline his next statement] *¿Qué conecta eso que funciona?* 	Knowledge building & Emotional engagement /Co-facilitator
5	JACOB [Reaches out to touch the device anxiously before shrugging]	
6	**JOAQUIN** [Switching his gaze from the device (still being manipulated by Jacob) towards Jacob] We did this last time.	Continuity /Co-facilitator
7	JACOB [Smiles while laughing and mumbling something in response]	
8	**JOAQUIN** This is a review, Jacob.	Continuity /Co-facilitator

9	JACOB This one. [Points towards a component on the device.]	
10	**JOAQUIN** *¿Cuál?*(Pause) This one? [Raises himself over the table, pointing towards the component Jacob indicated before looking back at Jacob] 	Knowledge building /Co-facilitator
11	JACOB [Nods in agreement.]	
12	**JOAQUIN** How do you know that? [Looking at Jacob.]	Knowledge building /Co-facilitator
13	JACOB Because, it's what turns it on.	
14	NGON If you don't know you can just hold the wire and see where it takes you. [Grabs the Raspberry Pi and briefly traces a wire.] [Joaquin hits the table three times with his fist in a moment of revelatory agreement.]	Knowledge building/Facilitator

15	[Jacob traces the wire to the plug before responding to Joaquin.] JACOB That. 	
16	**JOAQUIN** Yeah. [Joaquin glances at Ngon, then nods at Jacob.]	

Table 4

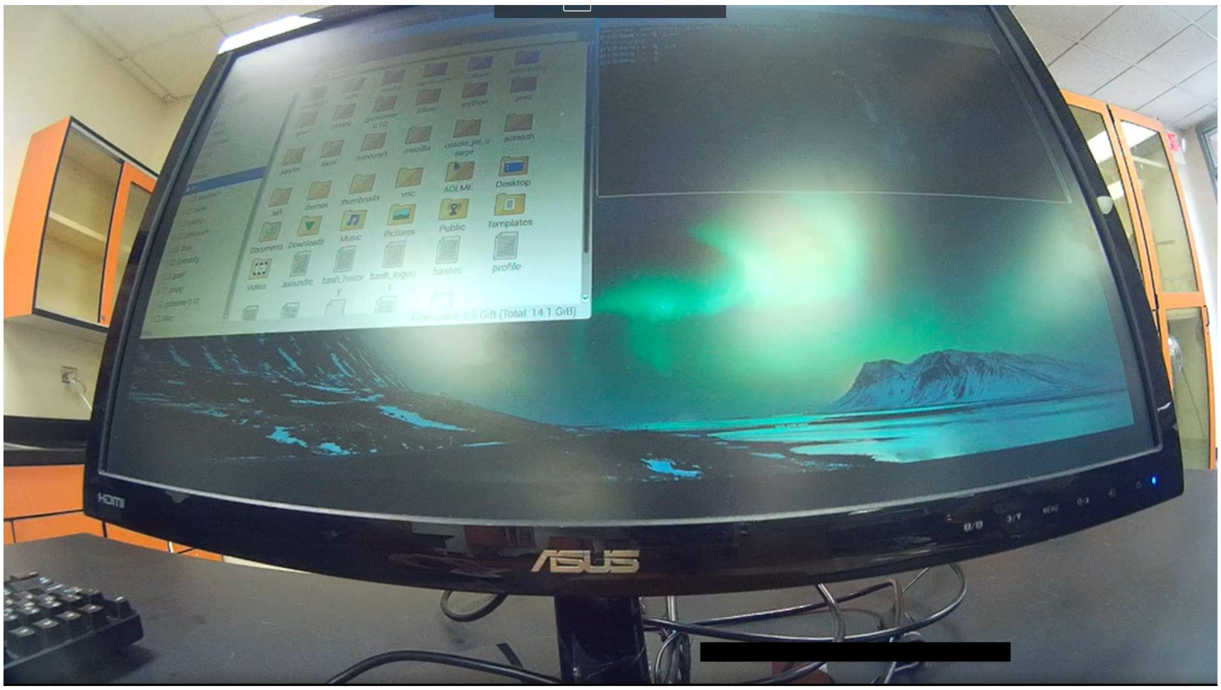
Translanguaging: Agentic Moment & Pedagogical Tool - Instance 2		
Turn	**Act**	**Pedg. Link/Source**
1	**JOAQUIN** [Speaking of the Ethernet & USB Controller] *Eso, tu lo hicistes con*…how that guy's name…Mario. You did that with Mario, and you know that was correct.  [Leans in close to Jacob] It's a…	Continuity & Emotional engagement /Co-facilitator
2	JACOB Mario?	

3	**JOAQUIN** Yeah. It’s a part that has, they look the same, one is smaller and one is big. [Uses finger motions to demonstrate the size difference between the two components.] 	Support knowledge building /Co-facilitator
4	JACOB Oh! This one here? [Reticently points towards a component after attempting to trace wired inputs to their sources] 	Knowledge building /Student
5	**JOAQUIN** Are you sure it's that one? [Points to the same component before covering his mouth with the top of his fist]	

6	JACOB [Points to a different component before glancing at Joaquin] Eh, this one.	
7	**JOAQUIN** [Still covering his mouth with his fist]] Why?	
8	JACOB I don't know. No, this one's the power…and..this one is? [Pointing to the power before switching to the processor]	Continuity /Student
9	**JOAQUIN** No. [Shaking his head before glancing at the instructional unit card]	
10	JACOB *Tsst! ¿¡quién sabe!?* [Pushing against the table, throwing his upper body backwards in frustration]	
11	**JOAQUIN** *Es la otra. Mira.*	Continuity /Co-facilitator
12	JACOB *Es este.* [Points at the correct component]	
13	**JOAQUIN** *Si. Sí. porque mira*, Ethernet-USB controller. See this is the one that sends to the other parts, right?	Knowledge building /Co-facilitator

Table 5

AOLME Programming Environment & Linux Commands



Command	**Description**	**Examples**
`pwd`	Print Working Directory. Prints the current directory name.	`>pwd` `  /home/pi`
`ls`	Lists the files and directories in the current directory.	`>ls` `  pi  readme.txt`

`ls -al`	Prints detailed information for each local file and directory. See detailed example.	`>ls`
		`drwx … pi`
		`-drwx … readme.txt`

`cd name`	Change Directory to name.
	
	/ refers to the root directory.
	. refers to the current directory.
	.. refers to the previous directory.
		`To make "/" the current directory:`
		`>cd /`
		`>pwd`
		` /`
		
		`To go back one:`

		>pwd /home/pi >cd .. >pwd

Table 6

Pedagogical Modeling: Ideas for Learning Virtual Systems and Linux Commands			
Concept/ Command	**File, Folder, Directory**	**LS Command**	**PWD Command**
Representation			
Composer	Ngon/Joaquin/Jacob	Ngon/Joaquin	Joaquin
Discourse	Ngon: In real life, what's the difference between folder and file? Joaquin: The files you put in the folder and the folder holds them. Jacob: The files are… information. They go in folders?	Ngon: So if you have a folder and you type-in *LS*, what does it do? Joaquin: I think it shows you, like, what files are in and how many folders.	Joaquin: If you type *PWD* it's going to tell you *C*.

Figure 1

Pedagogical Link-Making Approaches (Scott et al., 2011)

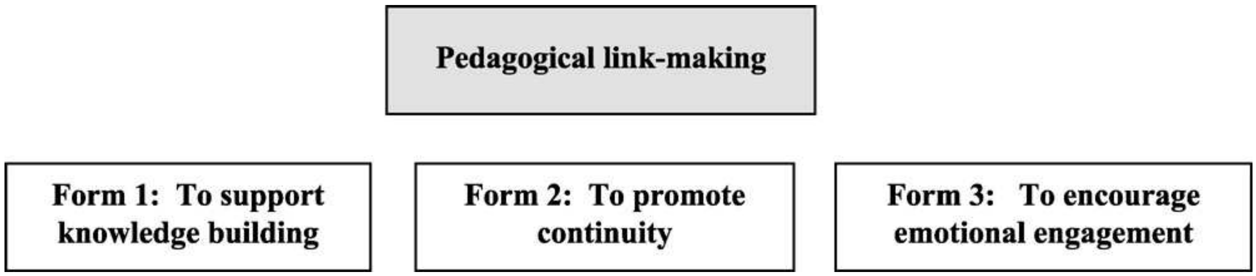


Figure 2

Instructional Card Used During the Learning Activity - Computer Components

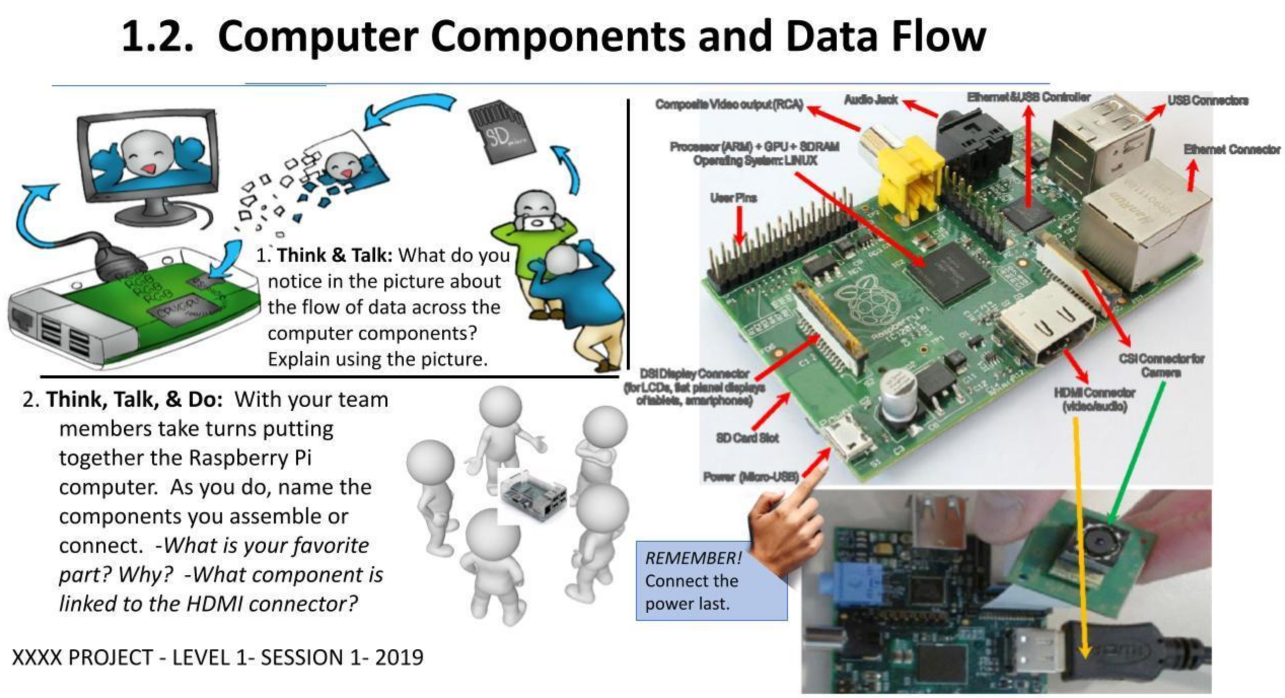
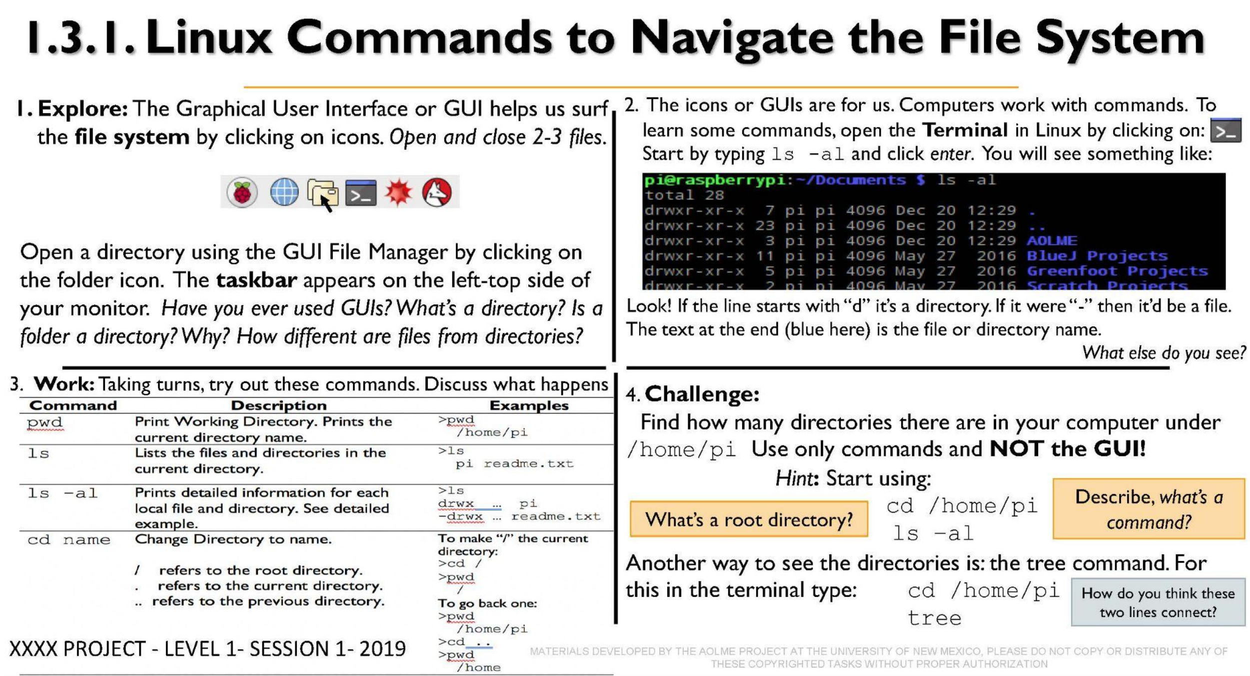


Figure 3

Instructional Card Used During the Learning Activity - Linux Commands



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