

LEARNING

Interaction rituals and inquiry-based science instruction: Analysis of student participation in small-group investigations in a multilingual classroom

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Abstract

Language learners participating in inquiry-based science instruction are often faced with the challenge of interacting in a language they have not yet mastered. With this challenge at the fore, this study uses interaction ritual theory to examine a plurilingual student's participation in inquiry-based science. Interaction ritual analysis of the focal student's interactions with peers during small-group science investigations at the microlevel (tenths of a second) and in real-time revealed that positive interaction rituals failed to form at first. Over a period of 6 months, his persistent use of nonverbal and verbal participation strategies, and opportunities to engage diverse communicative resources, resulted in higher levels of synchrony with his classmates and successful interactions in the language of instruction. The findings present novel information about the nuances of the silent, embodied participation of language learners in inquiry-oriented instruction. Further, the findings elaborate the claim that inquiry-based science pedagogies created space for students to form successful interaction rituals that, in turn, supported the focal student's science engagement and language development.

KEYWORDS

inquiry-based science instruction, interaction rituals, language learners, multilingual, plurilingual, student participation

1 | INTRODUCTION

Recent science education policy initiatives advocate the use of student-driven inquiry-oriented instructional approaches to engage students in the practices of science (NGSS Lead States, 2013; NRC, 2012; Rocard et al., 2007).

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These approaches position students to actively design and conduct science investigations and to participate in the practices of science as an avenue for learning. It is crucial that students have the means to participate in such practices, yet students who are language learners run the risk of missing opportunities for meaningful engagement when they are required to participate through languages they have not yet mastered. While research has documented that inquiry-based science instruction can create meaningful contexts for language development (e.g., Lee, Deaktor, Hart, Cuevas, & Enders, 2005), language can also act as a barrier that impedes student participation, thus reducing students' opportunities to learn through such instructional approaches (Lee, Quinn, & Valdés, 2013). To successfully support student participation in inquiry-based contexts, it is essential to understand students' use of and access to communicative resources and how access to these resources intertwine; first, in their engagement with group members and, second, with the practices of science.

Many classrooms throughout the world are experiencing shifts in the number of students who speak languages in addition to, or other than, the language of instruction (e.g., Camarota, 2007). In these classrooms, plurilingual¹ students are positioned to learn science through language competencies that they are still developing (Swanson, Bianchini, & Lee, 2014). This presents educators with the challenge of constructing learning opportunities that support participation for a range of learners and presents students who are language learners with the challenge of building science understandings while simultaneously building language skills (Lemke, 1990). There is a large and growing body of research that shows that when language learners engage in context-rich, student-driven forms of science instruction such as inquiry-based science, both science understandings and language competencies are developed (Lee, 2015; Lee et al., 2013). Student-driven science instructional approaches, such as inquiry-oriented science (NRC, 2000, 2012), can be particularly beneficial for plurilingual students who may not be proficient in the language of instruction, as they support dialogic engagement around science which can also serve to mediate their language proficiencies. While there has been an increasing trend in the research literature that considers students' language competencies in relation to their science experiences (e.g., Cuevas, Lee, Hart, & Deaktor, 2005; Llosa et al., 2016), there is a dearth of research that explores *how* language learners participate within the socially embedded structures of inquiry-oriented activities. More specifically, there is a need to understand how language learners employ communicative resources while engaging in the social structures of inquiry-based science instruction. One way of examining their engagement is through the methodological and analytical lens of interaction ritual theory (IRT).

2 | THEORETICAL GROUNDING

2.1 | Interaction ritual theory and interaction rituals in science classrooms

This study employed IRT as an analytical lens to examine plurilingual students' participation in inquiry-based science instruction. IRT theorizes that focused social interaction is the foundation of social life (Collins, 2004; Summers-Effler, 2006). When social actors come together and collectively engage in a task, interaction rituals can occur. Through this mutual engagement, synchrony can form in group members' movements, speech, and embodied interactions. Synchrony through IRT is conceptualized as movement and/or verbalizations among actors that occur at the same rhythm in an interaction (Collins, 2004). Synchrony produced through successful interaction rituals occurs on microlevels that can be imperceptible in real time. When positive, the successful interaction ritual charges participants with positive emotional stores that can be accessed during later interactions and that can result in feelings of confidence and pride. Interaction rituals can be as brief and routine as how we greet someone when walking down the street, or can be larger events in space and time, such as a political march or a sporting event.

Rooted in the sociological theories of Durkheim (1912/1965), and later elaborated by Goffman (1967), IRT (Collins, 2004) supports analysis of interaction at microlevels to provide insights into the foundations of human interaction. Collins (2004) details how humans seek out interactions in ways that generate positive emotions, and that, if these positive emotion-generating interactions are repeated, the results can lead to entrainment and synchrony in a group in the short term and solidarity over the long term (Figure 1).

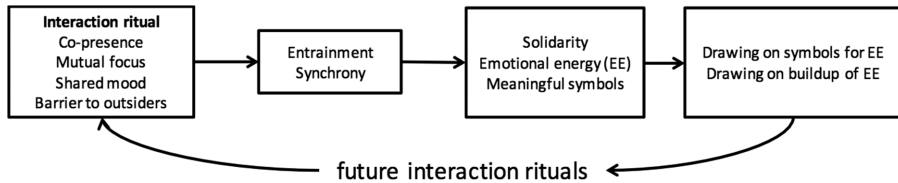


FIGURE 1 Interaction ritual chains as conceptualized by Collins (2004) and adapted from Summers-Effler (2006)

According to Collins (2004), there are four basic interaction ritual ingredients. These include being copresent in a group, mutually focusing on a task, sharing a mood, and a barrier to outsiders of the group (Figure 1). When the four ingredients are present, synchrony can form on the level of microseconds and build among participants. As a result, shared emotional energy (EE) is generated among members of the group that can turn into feelings of solidarity. The EE that is generated in the interaction ritual can be positively or negatively valenced and, when present, varies in intensity. When it is positive, it can result in feelings of pride, contentment, and joy. When it is negative, it can result in dejection or demotivation. The EE that is generated can also become embedded in meaningful symbols. These symbols then can inspire further feelings among group members who associate the symbols with the group's interactions. Think of soccer fans, and the symbolism of a team jersey. These group-generated symbols (the team jersey) can be accessed at future points in time to tap into the EE generated by the prior interaction ritual (the positive emotions experienced at the prior soccer game). Participants may draw on these symbols for generating further EE and seek future interaction rituals that lead to further shared EE (Collins, 2004). This can occur in a chain, with one successful interaction ritual leading to another, and does not necessarily need to occur with the same actors. Interaction ritual chains are significant in that they provide a conceptualization of how EE can build in one group context and be transferred to new situations.

IRT and interaction ritual analysis has proved to be a useful tool for analyzing interactions in science education contexts in general (e.g., Bellocchi, 2017; Olitsky, 2017), and in classrooms in particular (e.g., Elmesky, 2015; Milne & Otieno, 2007; Olitsky, 2007). In one study, Elmesky (2015) utilized video microanalysis to examine interaction rituals present in teacher–student and student–student interactions in a high-school chemistry class. Discussions with participants during analysis about specific moments of observed synchrony or asynchrony revealed that, first, the teacher made many unconscious moves that structured students' focus on the science activities and, second, students involved in the same activities responded differently (some positive, some negative) to the teacher's moves. Thus, interaction ritual analysis revealed how unconscious teacher moves could support or work against successful student engagement.

Similarly, Olitsky (2007) showed how an examination of interaction ritual chains between a teacher and her eighth-grade chemistry class revealed teaching practices that resulted in both successful and unsuccessful interaction rituals. The teacher, in an attempt to make science instruction more accessible, included popular culture examples in her lesson. Olitsky's (2007) analysis demonstrated how during the teacher's attempt to increase student engagement, successful interaction rituals failed to form. Contrary to the teacher's intent, a break in whole-class synchrony occurred that was observed on the microlevel (tenths of a second), resulting in a decline in student engagement. Olitsky's work demonstrates how microanalysis can reveal intricacies of classroom interactions that while both verbal and nonverbal, are often not conscious, yet that have direct consequences on student participation and learning. When considered together, these two studies (Elmesky, 2015; Olitsky, 2007) demonstrate how analysis of interactions in science classrooms through the lens of IRT can provide novel insights into contexts of teaching and learning.

This study builds upon previous science education research employing microsociological analytic approaches to examine the participation of language learners in inquiry-based science investigations. IRT focuses on interactions between individuals, and principles from microsociology allow for examining individual roles and interactions. The power of using IRT as a theoretical lens is that it facilitates analysis of engagement across micro- and mesolevels of interaction as it foregrounds both verbal and nonverbal communication resources and reveals how they mediate group

interaction. Thus, interaction ritual analysis has the power to reveal layers of interaction that might be missed through the sole use of language-based analytical lenses.

2.2 | Plurilingual students and teachers

In our research, we employ plurilingualism as a lens to examine the communicative events and interactions in which students and teachers engage (e.g., Wilmes, Fernández Gómez, Gorges, & Siry, 2018). Through a plurilingual lens, students and teachers are viewed as actors who individually possess unique repertoires of communicative resources. Plurilingualism is distinct from bilingualism and multilingualism in that plurilingualism conceptualizes communication as the use of multiple communicative resources and hybrid forms of speaking (Silver & Bokhorst-Heng, 2013). This is different from bilingualism that conceptualizes speakers according to their use of one national language versus another. It is also different from a multilingual lens that posits that individuals draw upon multiple, yet distinct, sets of national languages. Plurilingualism, in comparison, assumes that there is always a blending and hybridity present in the use of communicative resources.

The notion of plurilingualism was adopted by the Council of Europe (2001) as an orientation toward language education policy in Europe and has since been used more widely in applied linguistics research as a way to more equitably view diverse communicative resource use (see, e.g., Canagarajah & Liynage, 2012; Piccardo, 2013). In this study, and in our research on the overall (e.g., Wilmes, Siry, Fernández Gómez, & Gorges, 2018), we use plurilingualism as a lens as it valorizes diverse communicative resource use and removes emphasis on the use of discrete sets of national languages. A plurilingual lens allows our research to consider the “full spectrum of a students’ linguistic repertoire as a resource for learning” (Piccardo, 2013, p. 617) in ways not often sanctioned in classroom policies. It allows our research to honor the hybrid, dynamic, creative, and fluid communicative moves of teachers and students in ways that are inclusive and that assume speakers always draw upon hybrid forms of communication. Use of a plurilingual lens positions our research to emphasize *resource-rich* (Siry, 2011) views of students’ communicative moves, rather than lenses that compare language users to native fluent users of single languages, which can lead to deficit views of students communicating in languages they have not yet mastered.

2.3 | Silent and embodied participation of language learners

It is widely established in sociolinguistics that language learners, when learning to interact in a new language, often experience a period of silent engagement (Bligh, 2014). This occurs as a learner is developing communicative competence but does not yet actively produce verbalizations in the new language. In her 2014 study, Bligh established the key role of silent engagement as an essential component of language learners’ classroom participation. Students learning to communicate in additional languages draw heavily upon the strategies of close observation, intense listening, and mirroring of modeled activities and interactions as essential processes that facilitate engaged, yet silent participation (Bligh, 2014). Through these silent interactions, students participate in classroom learning activities, and reciprocally the students’ knowledge, comfort with, and use of the language increase. Building upon this, interaction ritual analysis is a valuable analytical approach for examining students’ classroom participation as it provides an analytic mechanism for viewing embodied modes of interaction along with verbal modes. In doing so, it can reveal both the silent and spoken intricacies of students’ interactions.

As such, this study analyzes the ways plurilingual students engage with each other and with language resources as they participate in inquiry-oriented instructional units. Specifically, it presents the case of a plurilingual student named Teo,² who participated in inquiry-based science investigations through a language he had not yet mastered. Interaction ritual analysis illuminated how he interacted within four different small-group inquiry-based science investigations over a 6-month period. Two questions are explored:

1. What interaction rituals formed in his work with four different small-groups over a period of six-months?
2. What does analysis of these interaction rituals reveal regarding his language use and participation in science practices within the context of inquiry-based science instruction?

3 | METHODOLOGY

This study employed IRT as an analytical lens to examine the interaction rituals and synchrony that formed when a multilingual class engaged in inquiry-based science instruction.

3.1 | Integrated inquiry-oriented science and language instructional program

The study presented herein was conducted as a subset of a larger research project that examined the use of an integrated inquiry-based science and language literacy pedagogical approach, titled *Science Workshop*, in multilingual elementary classrooms in Luxembourg (Wilmes, 2017a,b). Analysis focused on three science units implemented in a multilingual classroom over a 6-month period (Table 1).

Each unit consisted of student-driven inquiry-based activities designed to engage students in posing questions about science phenomena, and through multiple rounds of designing and conducting investigations to explore their questions. Learning activities were conducted in varied social configurations (individually, in pairs, in small groups, and with the whole class), both within each unit and across the three units. Inquiry activities were structured to scaffold the linguistic demand of the science tasks, and thus each inquiry-based unit supported both science and language learning (Wilmes, 2017a). Across all three (Table 1), the inquiry-oriented instruction was parallel in form and incorporated similar tasks with the goal of engaging students in science practices through student-driven inquiry.

A team of four coteachers including the classroom teacher and three teacher-researchers worked with the class. Throughout each phase of inquiry, all four teachers upheld the expectation that all students would participate in diverse ways, and opportunities for participation were facilitated through two specific strategies. First, each inquiry task was structured so that students had opportunities to participate in a more contextually supported, less linguistically demanding way (e.g., discussing questions in pairs) before engaging in more demanding tasks (e.g., writing them individually in their science notebook). Second, students were encouraged to utilize varied multimodal communicative resources (e.g., drawing, short narrative descriptions, photos) during each phase of inquiry. This created the expectation that all students would participate in all phases of inquiry through the flexible use of communicative resources.

3.2 | The plurilingual student participants

This study was conducted in Luxembourg, a multilingual country with a trilingual primary school curriculum (Luxembourgish, German, and French). The trilingual national elementary school curriculum expects students to be proficient in the three languages before completing primary school. Relevant for the research presented herein, students learn science in German starting from age six (Ministère de l'Éducation nationale et de la Formation professionnelle, 2011). The analysis presented herein arose from the use of the integrated inquiry-based science program at City Primary, a midsize elementary school serving approximately 350 children in Luxembourg City, in one fourth-grade class

TABLE 1 Overview of three inquiry-based science units

	Water unit	Soil unit	Soil dwelling organisms
Science content	Condensation and evaporation	Composition and physical properties of soil	Characteristics of organisms
Science processes	Generating questions from observations Designing and conducting investigations Communicating results		
Duration	5 classroom sessions	3 classroom sessions 1 outdoor session	1 University-workshop session

(10–11 year-old children). The class consisted of 15 ethnically, social-economically, and linguistically diverse students. All 15 plurilingual students possessed communicative skills in differing combinations drawing from multiple national languages. This complex linguistic landscape reflects the national linguistic diversity (Peltier & Klein, 2018). This is a crucial component of the analysis presented in that all of the student participants were learning science through German, a language many of them were still working to master, and only one of several languages in their repertoires.

3.3 | Teo: The critical case of a plurilingual student

Of the 15 plurilingual student participants, Teo was selected as a critical case based on four criteria. First, initial video analysis revealed that Teo did not verbally participate in whole-class discussions in German, the language of science instruction. Second, during less-structured classroom moments Teo often spoke to the research video cameras in French. Third, during student interviews Teo explained that he speaks French most often in out-of-school contexts, including at home. This is significant as in Luxembourgish elementary classrooms, French is primarily relegated to French literacy lessons. Thus, students are not typically encouraged to use languages other than German or Luxembourgish while learning science. Lastly, Teo's teacher identified him as having weak proficiency in German and as a result, he was at risk of repeating the school year. Based on these four criteria, Teo was selected as a critical case (Patton, 2015) to focus analysis on the participation of a language learner in the context of inquiry-based science instruction.

Rooted in an understanding of the collective nature of interaction (Bellocchi, 2017), analysis examined Teo's work within four student triads over a 6-month period (Figure 2). In these four triads, Teo worked with five additional plurilingual students (Table 2).

4 | METHODS

This qualitative study analyzed interaction rituals as they unfolded during elementary science instruction across both micro- and mesolevels of interaction in a multilingual classroom. We situate our work within sociocultural views of science and engagement in classrooms (Tobin, 2012) and language resource engagement (Creese, 2008). As such, our research views science as a contextualized practice that unfolds in interaction as students collectively mobilize resources (Siry & Max, 2013). Arising from this theoretical stance, our research employs qualitative methods that examine socially situated and contextualized student and teacher interaction and that honors the culturally embedded tools they access during science investigations.

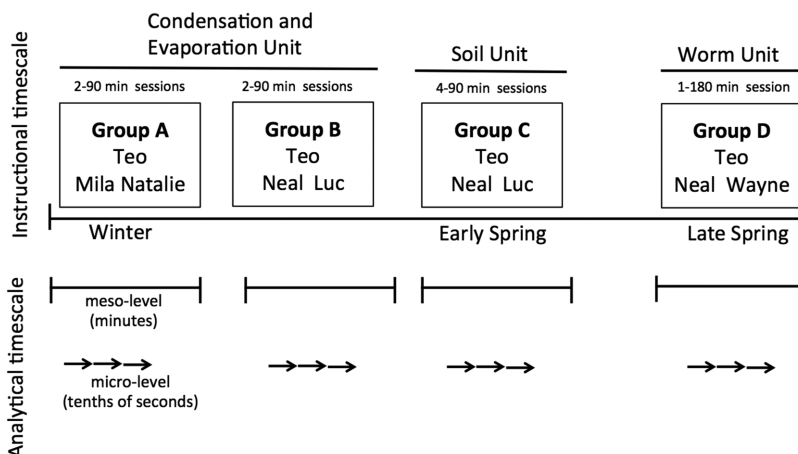


FIGURE 2 Analysis across micro- and mesotimescales for four student groups across three inquiry-based units

TABLE 2 Student language repertoires compiled from student interviews

Name	Luxembourgish	German	French	Bosnian	Montenegrin	Russian
Teo (focal student)	X		X			
Mila		X	X			
Natalie					X	
Luc		X	X			
Neal	X	X		X		
Wayne	X					X
Role in Luxembourg primary curriculum	Secondary content instruction (Music, Art)	Primary instruction (Literacy, Science, Math, Geography, History)	As a subject			

X denotes a language spoken at home. Black box denote languages with an official place in the trilingual primary school curriculum.

4.1 | Data sources

Over the course of 6 months multiple data sources detailing students' participation in three inquiry-based science units (Figure 2) were collected. Data sources included whole-class videos, small-group videos, learning artifacts, and semistructured student interviews. Tabletop video cameras captured close-up videos of small-group work. All artifacts produced by individuals, triads and the class were collected and archived and included student science notebooks, class posters, and student question cards. Semistructured student interviews were conducted at the culmination of the Water unit. The interviews revealed students' self-identified linguistic repertoires (Busch, 2012), and provided students' reflections on their instructional experiences.

4.2 | Data analysis

A multilayered analytic approach afforded views of student interactions across both microlevels (tenths of seconds) and mesolevels (minutes) of interaction (Elmesky, 2015; Olitsky, 2007, 2017). The first layer of analysis at the mesolevel involved viewing all classroom videos in real time and logging the learning activity structures (e.g., whole class, small group), participants, and communicative resources employed for each activity. A process of purposeful sampling was next used to identify focal student groups who used languages other than the language of instruction (German) either in interactions or in written productions. This led to the selection of Teo as a critical case (Patton, 2015) based on observations of his reluctant use of German with teachers and preference for French, as revealed through interviews and observations.

A second layer of video analysis examined group interactions in each of the triads Teo worked within across both micro- and mesotimescales. This involved the construction of multimodal transcripts from video sources (Siry, Ziegler, & Max, 2012) documenting Teo and his groupmates' interactions in order to identify the content and purpose of verbalizations, and language resources employed, first at the mesolevel in real time, and then at the microlevel (one tenth of one second). Viewing video footage frame by frame allowed for identification of the presence and form of interaction ritual ingredients including, bodily copresence, mutual focus, barriers to outsiders, and shared mood (Collins, 2004; Table 3). Embodied and verbal aspects of interaction, including proxemics, gaze, and verbalizations, were also incorporated in the multimodal transcripts in this second layer for each of the four student triads across both microlevels and mesolevels of interaction.

This multilayered analysis was next used to characterize the forms of synchrony that developed across both micro- and mesotimescales as well as the role of Teo as an assistant or director during science investigations (Siry, Wilmes, & Haus, 2016), and his use of language resources. Taken together, multilayered characterizations of synchrony and interactions across both meso- and microlevels (Elmesky, 2015) were compiled for each of the four groups. All data sources

TABLE 3 Characterizing interaction ritual ingredients in small-group interactions

Interaction ritual ingredients	Characterization at the microlevel
Copresence	<ul style="list-style-type: none"> • Position of group members relative to focal interaction • Position relative to multiple participants
Mutual focus	<ul style="list-style-type: none"> • One focus, multiple foci, no focus • Duration of mutual focus • Gaze, body position relative to mutual focus
Barrier to outsiders	<ul style="list-style-type: none"> • Do others visit the group? How often? Whom? • Do members of the group leave? How often? For how long? • Do members set up barriers through linguistic means, physical means, emotional means?
Shared mood	<ul style="list-style-type: none"> • Mood (positive, focused, enthusiastic, angry, agitated) • Do group members share the mood? • How long does the mood persist?

were analyzed in their original language, meaning in the language in which they were produced. Multiple researchers who speak French, German, and/or Luxembourgish used standardized procedures to construct multimodal transcripts of focal moments (Wilmes, 2017b) which were cross-checked by additional researchers for accuracy. Verbalizations were subsequently translated into English for research dissemination and publication. English translations were conducted by plurilingual researchers and cross-checked by additional researchers to ensure accuracy. Results from data analysis were shared with research colleagues from several different institutions at multiple points during the analytical process to discuss claims that crystallized from analysis.

5 | SMALL-GROUP SCIENCE INTERACTION RITUALS

The analysis that follows details the forms of synchrony that developed in the four small-groups Teo worked with over a 6-month period. An overall characterization of the synchrony that developed will be presented for each group, followed by analytic discussion describing Teo's participation and language use (Table 4). Excerpts supporting each characterization that draw from analysis across both microlevels (tenths of a second) and mesolevels (minutes) of interaction will be presented.

TABLE 4 Synchrony, role, and language use in four student groups across three science units

		Evaporation and condensation unit		Soil unit	Soil dwelling organisms
		Group A	Group B	Group C	Group D
Students in group		Teo, Mila, Natalie	Teo, Luc, Neal	Teo, Luc, Neal	Teo, Neal, Wayne
Group synchrony		Asynchronous	Offset synchrony	Synchronous	Synchronous
Teo's role in investigation		Recorder	Assistant	Director and assistant	Director and assistant
Teo's German usage	With teachers	Silent engagement	Silent engagement	Silent engagement	Initiates verbal interaction
	With peers	Structured by activities	Structured by activities	Structured by activities	Structured by activities

5.1 | Group A: Asynchrony

In Group A, Teo worked with Mila and Natalie (Table 2, Figure 3), for 40 minutes to design and conduct a science investigation exploring their questions about condensation.

Analysis of their work revealed that Teo's interactions were engaged, yet asynchronous across multiple aspects of interaction. For the majority of the investigation Teo frequently looked over Mila and Natalie's shoulders (Figure 4a,b). As a result, he did not have a direct role in material manipulation during the course of the investigation.

As the investigation continued, Natalie took on a lead role. She turned at one point toward Teo and commanded, "You must help me!" as he stood looking toward her with his hands at his sides. Participatory science investigations, such as those that were used in this classroom, structure group interactions in ways that allow members to negotiate group roles. This negotiation can provide all members with access and result in equal roles when conducting science investigations, or unequal access with some delegated to assistant-type roles and with less access to decision-making and material engagement (Siry et al., 2016). The latter was the case for Teo in Group A. Teo followed the directives set by Natalie and Mila. This was apparent in multiple interactions that followed, such as when Natalie told him, "Teo! Give me that!" while indicating he should hand her a pipette. In response, Teo looked away, and then walked to another group. During the 40-minute investigation period, Teo was observed traveling to other groups four distinct times. Collins' (2004) theorizing of interaction rituals explains that humans seek out positive EE and interactions that will lead to the production of more positive EE. Thus, Teo's leaving is indicative of less cohesive copresence among the group members and is interpreted as an embodiment of his search for a group with which he could form more positive interaction rituals, and subsequently participate in a more positive emotional climate. As such, Teo's encounters in Group A were characterized as *asynchronous* (Table 4).

Ten minutes into the investigation with Group A, Teo began to repeat Natalie's motions. She first raised her finger. Teo repeated this motion (Figure 5a). Then she lowered her arm, with her elbow bent. Teo mirrored this additional movement (Figure 5b).

This was interpreted as Teo's attempt to break through the low level of positive collective EE and to try to change his position within the group. Research conducted by Sullivan and Wilson (2013) investigating the role of playfulness in small group interactions during science lessons concluded that mimicking movements, such as Teo's, can be seen as a student's attempt to affect their position in a group, and to strengthen bonds toward the goal of increased group coordination. What followed Teo's playful repetition of movement was central to the interpretation of this interaction

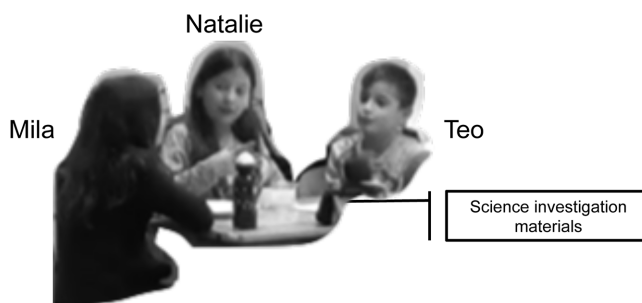


FIGURE 3 Teo worked with Mila and Natalie on a science investigation



FIGURE 4 Teo was consistently positioned farther from the investigation than Mila and Natalie



FIGURE 5 Teo mirrored Natalie's motions

and understanding his attempt. Natalie and Mila made frustrated faces and gestures toward Teo and maintained their bodies positioned away from him, but toward the investigation, and they worked on without engaging with Teo. In summary, his bids to participate did not result in increased positive interactions with Mila and Natalie.

Analysis of Teo's language use in Group A identified several key moments during the 40-minute investigation period regarding his use of the language of instruction, German. At several points when a teacher approached the group to discuss their progress, Teo remained engaged through gaze and body orientation but moved to a peripheral position. As previously elaborated, one of the instructional goals of this Science Workshop unit was for students to communicate about their investigations in both written and spoken German. Toward this goal, the teacher conversed in German with the group and maintained a body position and gaze directed toward all three group members in ways that were inclusive of Teo. Natalie, and Mila replied to the teacher in German with detailed explanations about what was occurring. Teo maintained his gaze toward the teacher and his group mates from his noncentral position. He nodded at several points, indicating embodied engagement, but did not participate verbally. Research on the silent participation of students immersed in new language environments reveals that their participation, while silent, is revealed through their gaze at a common focal point, and their body position oriented toward the focus of the conversation (Bligh, 2014). Teo repeatedly engaged silently in German interactions with teachers at several points during his work with Group A.

Video analysis revealed that Teo initiated spoken interactions in German only when the teachers set the expectation that German be used during specific activities, and only when a teacher was *not* present in the interaction. In the next moment presented (Excerpt 1), the teacher instructed the class to *describe what happened with your investigation. Write what happened or draw what happened in your science notebook.* After receiving these instructions, Teo turns to his group and mirrored the teacher's phrase in German, *Natalie, I am writing what happened* (Excerpt 1, line 01) and the following interaction ensues:

EXCERPT 1: Teo attempts a conversation in German³

Line	Speaker	Talk	Action
01	Teo	I am writing what happened.	Looking toward Mila and Natalie (Figure 6a)
02	Natalie	O::kay	Facing materials, hands on a metal plate
03	Teo	What happened here?	Leaning in toward materials and pointing toward materials with a pipette
04		Natalie, what happened?	
05	Natalie	So...Hhhggghh, FINALLY!	Rearranges the materials on the table in front of her
06	Mila	And what are we doing now Natalie?	Picks up tin pan while looking at Natalie
07	Natalie	Aaag.... Now we need tape. Get two big pieces.	Working with the materials on the table and speaking to Mila
08			Teo turns away from Mila and Natalie and writes in his science notebook at the opposite end of the table. (Figure 6b,c)

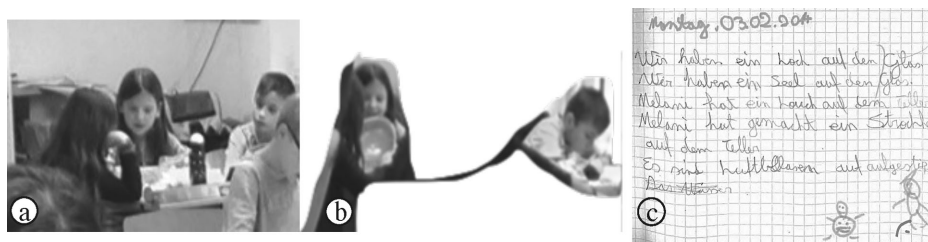


FIGURE 6 Teo sat to the side of Group A (a) watching as Natalie and Mila work. After attempting to converse with them in German, he turned to the side (b), and wrote a detailed science notebook entry (c) describing the group investigation

Natalie acknowledged his statement with *okay* (line 02) and continued to manipulate the investigation materials. Teo asks Natalie, in German as he points to the materials with a pipette, *What happened here?* (Excerpt 1, line 03, Figure 6b). In this moment, he repeated the German phrase provided by the teacher (*What happened?*) three times. Teo used this repetition strategy often. He drew upon language structures provided by instructional activities, in this case the question, to structure his interaction in the language of instruction.

Teo's attempt to engage Mila and Natalie in German by repeating *What happened?* (lines 03 and 04) failed, and Natalie instead spoke directly to Mila (line 07). Nevertheless, Teo turned away from his group mates (Figure 6c) and wrote an entry in his science notebook. The level of detail in his entry (Figure 6c) demonstrates Teo's awareness of the progress of the investigation, regardless of the asynchrony that occurred in interaction with Mila and Natalie. Analysis of student interviews supported conclusions drawn from video analysis in that both Mila and Natalie described being frustrated with Teo and explained that they felt he did not contribute to the investigations. In sum, Teo's interactions in Group A were characterized as asynchronous (Table 4).

5.2 | Group B: Offset synchrony

In Group B, Teo worked within the same Water unit, but with a two different students, Luc and Neal (Figure 2). Student interviews revealed that at home Luc speaks French and German, and Neal speaks Luxembourgish, German, and Bosnian (Table 2). This is relevant to analysis, as Teo shared French as a home language with Luc and was often heard speaking Luxembourgish or French with Luc, but only Luxembourgish with Neal.

Group B was engaged for the 40-minute investigation as revealed in their mutual focus to complete their investigation. They moved fast to collect materials and had quick interactions with little verbal elaboration as they moved materials into place, checked next steps and executed their plan. In comparison to Group A, Group B exhibited a higher degree of bodily copresence, indicated by a longer duration of time spent together in a circle with a tighter radius, focusing on the same investigation. As a result, a buildup of positive EE developed. Video analysis of Group B's interactions across micro- and meso-timescales revealed a buildup of synchrony that was offset or delayed by an interval of tenths of seconds to minutes. This form of delayed synchrony we term *offset synchrony*. Offset synchrony differs from synchrony in that it forms when the ingredients for interaction rituals are present and group members' motions and/or verbalizations occur with similar rhythm but are offset in time or space. Thus, the interaction ritual results in weaker EE generation than results from more positive forms of interaction rituals. Key moments that illustrate this offset synchrony are presented in the sections that follow.

Group B started by discussing their plan to investigate condensation and evaporation. Neal, speaking in Luxembourgish, presented his plan with his body and gaze turned toward Luc. Teo watched their interaction without participating verbally (Figure 7a, b). Next, Teo asked Neal in Luxembourgish, *What is that?* and pointed to the plan illustrated in Neal's science notebook (Figure 7c). Neal explained to Teo each of the elements shown in his notebook, and then Teo declared, *Okay, I will do that too*. Teo then constructed the same entry in his notebook (Figure 7d).

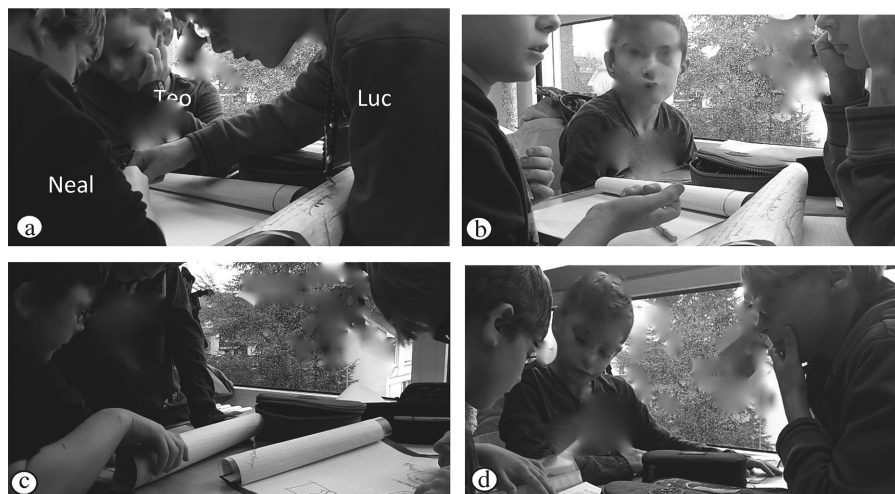


FIGURE 7 Teo watched Neal and Luc as they discuss the group's investigation plan (a, b). He then asked Neal what he recorded in his notebook (c) and explained he would record the same plan as well (d)

In this moment, Teo again successfully employed a mirroring strategy to participate in the planning phase of the condensation and evaporation investigation. This was a strategic move on Teo's part to access the plan and resources made available to him through his group. Teo remained engaged with Luc and Neal as revealed through his body positioning and gaze and recorded the same plan as them but offset by several minutes.

Offset synchrony is again displayed minutes later as the group conducted their investigation. Teo was engaged, with his gaze and body orientation angled toward the materials, but he was one-step back from Luc and Neal and the investigation materials. As a result, Teo rarely directly manipulated the materials with the group (Figure 8). Teo was seen retrieving supplies from the supply table, but then handed them over to Luc and Neal. As such, he acted in the role of assistant. During one specific moment, Luc and Neal both walked away from the table. Teo moved quickly and directly in toward the table. He picked up the materials and executed the exact moves with a magnifying glass and metal pan that Neal and Luc had conducted just moments prior. Teo used their absence as an opportunity to move from his peripheral position to a more central position and repeated their actions.

At several points during Group B's investigation, the teacher approached and spoke in German to ask about their progress. During teacher-initiated interactions, Teo maintained his gaze and positioned his body toward the teacher, but he did not speak in German in the presence of the teacher. Additionally, Teo moved farther back from the teacher during the teacher-initiated interactions in German (Figure 9), as he did with Group A. This backward movement was interpreted as Teo's effort to distance himself from the German interaction, and yet to maintain silent engagement in the interaction. Analysis presented in subsequent sections will show that he repeated this form of interaction (prior in Group A and subsequently in Group C).



FIGURE 8 Teo watched as Neal and Luc performed the group's investigation

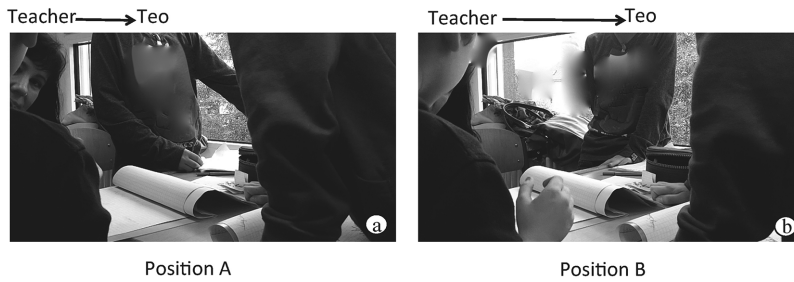


FIGURE 9 The teacher approached the group and began discussing their plan. Teo moved from his initial position (a) back to the windowsill (b) increasing his distance from the teacher and her interaction with Neal and Luc in German

Teo did not initiate interactions in German in Group B unless prompted to do so by an activity, or through the support of a peer. At one point, teachers asked the groups to write investigation questions on index cards as an informal record of students' questions. Teo, along with Luc and Neal, discussed the question they would record. During this 6-minute encounter, Neal playfully attempted to engage Teo and Luc in "making a movie" for the research camera. Teo and Luc ignored Neal's bids, and continued to discuss their ideas in both French and Luxembourgish (Figure 10a). Teo, in an emphatic moment, stood up, leaned closer to Luc and declared in French, *That is a question, in fact!* (Figure 10b) meaning that their idea was worthy of investigation and should be recorded on the index card. Teo's use of French in this enthusiastic moment, coupled with his body movement in standing up over the table and leaning in toward Luc is interpreted as a move to interact more strongly with Luc, and an attempt to override the playfulness in the moment initiated by Neal. By using French, Teo was able to participate directly with Luc, and place a barrier between them and Neal. This was supported by what Neal described later during his student interview as he explained that that he does not feel comfortable speaking French, and that he does not speak it with his classmates. Thus, Teo utilized these linguistic resources and strategies to form a stronger interaction between himself and Luc.

Following Teo's use of French to discuss the question, Luc replied in German, *Why does (the rain) only drip on Ronny?* (Ronny was a character in the science problem the students were investigating). Teo immediately sat down and began writing the question in German on the index card (Figure 10c). Then repeated back to Luc slowly in German, *Why did it drip...why did it drip...* he says, sitting up and looking directly at Luc, and again repeats with more force *DRIPPed, dripPED* (lines 4 and 5). In this moment, Teo's gaze toward Luc, coupled with his emphasis in tone and force when he works to pronounce dripped and the sequence of the interaction (writing-speaking-looking down, then repeating with



FIGURE 10 Teo listened as Luc and Neal spoke (a). Teo interjected in French (b), then wrote the question on an index card (c), and shared a smile with Luc (d).



FIGURE 11 Teo waited with his hand raised as another student spoke (a), and then enthusiastically tried to get called upon (b). When called upon he read the questions from the index card in German (c)

EXCERPT 2: Teo reads his group's question to the class

Line	Speaker	Talk	Action
01	Teo	Why did it dri::p only on Ronny?	Looking down and reading from the index card
02	Teacher	Why what?	
03	Teo	Why did it drip	
04		DRIPped	
05		dripPED	
06		only	
07		only on Ronny?	

force-looking at Luc) was interpreted as Teo checking that he had written the correct question in German and had pronounced it correctly. Teo follows this by looking back down at the index card, and while writing in a quieter and more drawn out voice, saying, *dri::ped ... on Ronny*. In this moment, Luc assisted Teo in writing the question in German. Positive emotion built up through this successful interaction, as was visible in the momentary smiles Luc and Teo shared immediately following their interaction (Figure 10d).

Summers-Effler (2006) in her ethnography of small group interaction rituals, explains that “The emotional consequences of (group) successes mark symbols in their interactional environment with emotional significance” (p. 148). In Group B, Teo and Luc recorded a question they were proud of on the index card. In turn, the question became imbued with positive emotional significance. This question became a symbol of the group's positive interaction rituals and charged Teo with positive emotion. This process is key in what it appeared to mediate in interaction 1 hour later.

The teachers next convened a whole-class discussion and asked students to share their questions. Teo raised his hand to participate in the discussion before the teacher finished giving instructions. While not explicitly stated, whole-class conversations were conducted in German. The students additionally always chose to speak in German, mirroring the language used by the teachers during these discussions. The teacher first called on another student. Teo remained with his hand raised, holding the index card while the other student spoke to the class (Figure 11a). Teo made anxious sounds and appeared eager to share as his hand was raised and waving during the other student's turn at speaking (Figure 11b). The teacher then called on Teo and he spoke in German in front of the class as he read from his index card (Figure 11c). Excerpt 2 details the interaction that developed with the teacher in front of the whole class.

As Teo spoke, he was uncertain about how to pronounce the verb “drip” (*tropfen* in German) and read it from the index card (Excerpt 2, line 01). He attempted multiple times to say the words while emphasizing different syllables (lines 04 and 05) similar to his emphasis of the same word when writing the question on the card with Luc. The index card served as a symbol from the past successful interaction. Teo enthusiastically initiated speaking in front of the class in German with the written question on the index card as support. The card and the positive emotion that went into its production was carried forward and served to support Teo's speaking to the whole class in German at this later point.

Overall in Group B, a low level of synchrony developed that, although slightly asynchronous and offset in time, served to mediate Teo's participation in Group B.

5.3 | Group C: Synchrony

In Group C, Teo worked again with Luc and Neal, but on a different unit exploring the nature and properties of local soil samples. For the duration of this unit, all three group members embodied higher levels of synchrony than were observed in Groups A or B. As such, Group C's interactions were characterized as synchronous, meaning displaying movements, utterances, and gazes that occurred in tandem at rates that were parallel as detailed in the sections that follow.

Many positive successful interaction rituals were seen, which resulted in both verbal and positional synchrony among the members of Group C. In these moments, (Figure 12a-c) the group was mutually focused on exploring the color of dry dirt, versus wet dirt, versus dirt mixed with ink. The copresence of Teo, Luc, and Neal at the investigation table was visible in their close and equal proximity to the science materials, and to each other. They passed materials back and forth, while focusing on the investigation materials in front of them. Their facial gestures often mirrored one another and were passed from one group member to another. This happened as one student made a facial expression that was held by the first student, and then passed to the other two students until the entire group shared the same facial expression (Figure 12a).

One particularly notable episode of synchrony occurred while the group used a microscope to examine soil grains. The three students stood with overlapped bodies (Figure 12b). Their heads moved simultaneously toward the microscope, their hands worked at the same tempo to move the focus knobs, as all three students attempted to look through the ocular lens simultaneously. Their movements and positions were highly synchronous.

In these investigations, Teo's was positioned as both a director of investigations and as an assistant. This is in direct contrast to his work with these same students' months earlier in Group B. In Group C, he spent equal amounts of time directing the group in executing his ideas and assisting in implementing his classmates' ideas. Over the four sessions of this Soil unit, many similar instances of synchrony, and expressions of positive emotion, were revealed through video analysis, indicating a series of successful interaction ritual chains.

For the majority of interactions in Group C, Teo, Luc, and Neal spoke Luxembourgish. Teo did not initiate interactions in German with Luc or Neal, nor with his teachers. When the teachers approached the group and spoke in German, Teo again positioned himself peripherally. This allowed him to silently engage without needing to speak German. At one point, students were asked to record observations of their soil sample in their science notebooks using the sentence starter, *I see* (in German). Teo used this sentence starter to frame his interaction with this group. Teo said to Neal, while laying his head briefly on Neal's shoulder, *I see...uh* (looking at the container of soil)...*an ant*. Teo next looked down at his notebook, then over toward Neal, then back to his notebook and then wrote the phrase "I see an ant" in German in his science notebook. Next he looked up again at the jar of soil and repeated in German, *I see...* (leaning over toward Neal, looking down at his notebook, then back at Student 5)...*uh...* (looking back into the jar of soil)...*small stones*. Luc echoed right after, *I see small stones* (in German), and Teo repeated after him in tandem with Neal, *small stones* almost simultaneously. This overlap in speech from both students illustrates how the activity structured both Teo's use of the phrase, *I see*, in German and how the three students repeated each other's phrases with a higher degree of synchrony



FIGURE 12 Multiple moments of verbal and embodied synchrony in Group C

than in Groups A and B. In summary, in Group C successful interaction rituals built up positive emotion in interaction ritual chains that fed into one another, and further mediated Teo's participation with Group C in German.

5.4 | Group D: Higher levels of synchrony

The fourth unit was run as a science workshop held at the university. The investigation period was one 3-hour session that utilized the same inquiry-based science investigation strategies used as in the two prior units (Table 1). For this session, Teo worked in a triad with Neal and Wayne (Figure 2). Video analysis of Group D's science practices revealed multiple elements of successful positive interaction ritual chains. First, the three members of the group were copresent and mutually focused around the investigation materials, as revealed through their body positions and gaze (Figure 13a,b). Mutual focus was maintained through synchronous interactions. A high level of copresence and mutual focus was particularly apparent during one moment when the group moved from one workshop room to another. Through this movement, they retained cohesive interactions, revealed through alternating lines of talk. This type of unbroken movement was characteristic of the high level of mutual focus and synchrony that video analysis revealed developed in Group D as they worked together.

Group D shared multiple moments of high positive energy with very enthusiastic embodied and verbal exchanges about the worms they were investigating. As they searched for worms and insects in their sample, they exclaimed in Luxembourgish, *I found one!* and a few seconds later, *I found another one!* They then returned to discussing their observations in more emotionally neutral tones. One particularly positively emotionally charged moment is presented in Excerpt 3. Teo and Neal were observing a container of worms as Wayne filmed their work using a handheld camera. Teo found a worm cocoon and proclaimed, *What a big cocoon!* At the same time Neal simultaneously proclaimed, *xxx another worm ...but BIGger*. This excited overlap in speech, occurring across several tenths of a second, was accompanied by rising intonations and occurred three times (Excerpt 3, lines 02, 04, 09 and 10) in an interaction lasting less than a minute. This form of overlapping speech is evidence of the group synchrony.

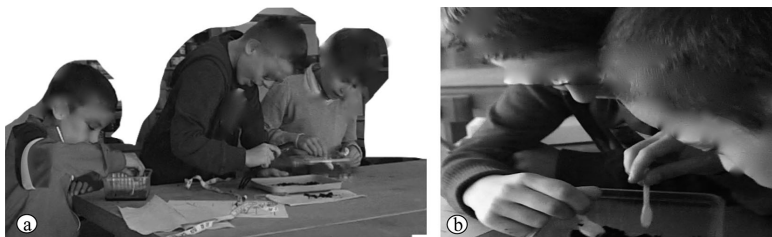


FIGURE 13 Group D mutually focused on observing worms and insects

EXCERPT 3: An emotionally charged, latched speech pattern in Group D interaction

Line	Speaker	Vocalization
01	Teo	What a big cocoon!
02	Neal	[xxx another worm...but BIGer]
03	Teo	Look there's a cocoon
04	Neal	[xxx]
05	Teo	Look a MEGA big one!
06	Teo	xxx the cocoon
07		There is a REALLY big one!
08		Oh yeah
09	Neal	[I found a really big one]
10	Wayne	[xxxx]



FIGURE 14 Teo walked up to the teachers (a, b) and initiated a conversation in German (c) about the cocoon he found

Video analysis revealed a notable change in Teo's German usage while working in Group D. At one point, Teo picked up a worm cocoon on a spoon and made three verbal bids to Wayne, in Luxembourgish to, *come*. Teo wanted Wayne to follow him with the camera back into the adjoining workshop room but Wayne did not respond to Teo's request. Teo then repeated *come*, three more times. As he repeated his request, Teo walked away from the group. Wayne eventually followed Teo's lead, and filmed Teo walking into the next room with the worm cocoon held on a spoon. A second camera angle of the episode revealed that Teo walked into the adjoining room and up to the three teachers who were standing in a circle (Figure 14a,b).

Once next to the group of teachers, Teo initiated an unscripted conversation in German, explaining what he found. Teo and the teacher discussed, through several turns of conversation in German and a mixture of German and Luxembourgish, the worm cocoon (Figure 14 c,d). The episode closes with the teacher and Teo engaging in a mutual positive exchange as revealed briefly across several tenths of a second in their gazes at and body positions oriented toward each other. Teo's initiative can be explained as the outcome of the buildup of positive EE from Teo's participation in successive positive IR chains both with this group and across the four inquiry-based units. This resulted in a buildup of positive emotions associated with working on science investigations and speaking in German which led to an increase in Teo's confidence. Teo's initiative was evidence of a buildup of positive EE through interaction ritual chains, which manifested as his confidence in initiating a conversation with his teachers in German.

Group D exhibited a higher degree of emotional and linguistic synchrony (Table 4). Teo directed science investigations and initiated a conversation in German with a teacher. The analysis presented shows that in the prior three groups, (A, B, and C), Teo made purposeful moves to avoid verbally engaging in German. In comparison, in Group D Teo initiated an unscripted conversation with the teacher in the classroom sanctioned language.

From this analysis, we make the claim that the use of inquiry-based science instructional practices over time afforded Teo the space to participate in positive interaction rituals, which when experienced repeatedly, lead to a buildup of positive EE. He was positioned to engage both silently and verbally in science practices and employ diverse linguistic resources in interaction. Across the four groups, Teo built upon successful positive interaction rituals and employed interaction strategies, specifically silent participation through close observation, intense listening, and mirroring, that helped him shift from acting as an assistant who moved away from interactions in German, to contributing as a director of science investigations and initiating conversations in German. The greatest levels of synchrony developed in Group D, the fourth group in which Teo worked. When working with this fourth group, Teo initiated an unscripted conversation with teachers in German, a first for him during this study. Thus, analysis revealed how over three inquiry-based units, Teo's embodied silent engagement transformed and through the support of successful synchronous interactions his participation became increasingly verbal.

6 | DISCUSSION

The study analyzed the case of Teo, a plurilingual student who worked within four different small-group investigations over a period of 6 months. Through his work in these groups on student-driven inquiry learning tasks, he was expected to communicate his findings in German, a language he had avoided using in past interactions with teachers

and in whole-class situations. Video analysis revealed different degrees of synchrony developed as Teo worked within each of the four groups and participated in repeated interaction rituals (Table 4). The positive EE that developed over time during these interaction rituals led to an increase in Teo's confidence, resulting in his initiative to seek out conversations with teachers in German. The main claim that arises from this analysis is that inquiry-based, student-directed science investigations mediated Teo's engagement in ways that resulted in his increased participation in science practices and his increased use of spoken German. Analysis presented shows how in each of the four groups Teo employed similar forms of silent engagement, namely mirroring, close observation, and silent engagement. When these forms of participation were successful, it assisted him in developing synchrony with his group mates which led to a buildup of positive EE over time. This, in turn, assisted him in initiating conversations in the language of instruction. He was able to move from silent participation to more verbally engaged forms of participation in German.

The results shown additionally speak to the multiple possible outcomes that can result when students engage in student-directed science investigations. While use of student-directed inquiry-based approaches are supported by leading policy documents (e.g., NGSS Lead States, 2013), interactions among students and with teachers can result in the exclusion of some. This is particularly the case for students who are not able, for one reason or another, to build positive interaction rituals through interactions with their classmates. Alternatively, student-directed investigations can provide spaces for students to flexibly draw upon diverse communicative resources and to repeat attempts to participate in varied forms of interaction, which can lead to positive interaction rituals and inclusive participation. The results we share underscore that it is important to be mindful of these possible variations in participation from an instructional standpoint.

While this study has shown that inquiry-based instruction supports student participation in ways that can foster synchrony and positive emotion in small groups, it could be postulated that Teo's participation differed from group to group as each was composed of a different triad of students. While this should be considered, we do not attribute the findings to this factor. Teacher interviews revealed that over the course of 2 years within this same class, Teo repeatedly worked with different constellations of students. Additionally, in this study Teo worked in Groups B and C with the same students, but different forms of synchrony resulted. These two factors show that Teo had experience working within different groupings, and yet at the time of this study he was still not initiating interactions in German during whole-class conversations, nor with teachers. Thus, based on analysis across an extended time period, we attribute Teo's participation in successful interaction rituals as related to his ability to draw upon diverse communication and interactional resources in the spaces created by the student-driven inquiry-based instructional approach. Further, the duration of time allotted to participating in inquiry, which varied dramatically from the teacher-centered forms used in science units prior to this study, was a key factor to his participation in successful interactions. Teo participated in numerous science lessons on the topics of water, soil, and soil dwelling organisms over the course of this study. This begs the question of whether the topics may have impacted Teo's successful interaction rituals. The varying nature of the content of the three units is not considered to have impacted Teo's participation in that during the units when Teo exhibited the lowest forms of synchrony and experienced unsuccessful interaction rituals with his own group members (Group A), he was observed traveling to other student groups with whom he briefly enthusiastically discussed his ideas.

Microlevel analytical approaches reveal moments in interaction that would have likely passed by unnoticed by both participants and researchers. Much of social interaction happens on a subconscious level (Collins, 2004). Thus, microlevel analysis supports a novel lens on interaction that allows views of the embodied, and subtle forms of synchrony that are not detected in real time. Thus, one of the greatest affordances of microlevel approaches is their ability to reveal interactional details that often go undetected. This is particularly important for research with language learners as nonverbal aspects of interaction are revealed that are key to engagement and participation.

Perhaps the greatest constraint of microlevel analytical approaches is to ensure how understandings revealed at microlevels relate to the larger, meso- and macro-context of the analyzed instructional situation. This necessitates that there is a zooming out in analysis, or else there is a risk that interpretation lacks a contextualized perspective. In this study, we worked to limit this constraint through multilevel analysis across both micro- and mesolevels, while additionally analyzing multiple perspectives, namely through the analysis of student and teacher interviews. These additional

perspectives complemented the microlevel video analysis in that they provided mesolevel perspectives of instruction and interaction in which we could situate the details revealed through microanalysis.

This study thus shows that ongoing opportunities for the generation of positive EE can lead to sustained participation in a diverse community of learners. This supports recent findings by Olitsky (2017) that demonstrated the development of synchrony on microlevels among professional teaching communities mediated their ability to work across cultural differences. In a similar way, we extend the findings of past interaction ritual studies to show herein how Teo, was able to work through his language differences toward participation in the class. This led to him taking on a central role in directing science investigations and to increase his initiation of conversations in the language of instruction.

7 | IMPLICATIONS

This study has provided an innovative view of the nonverbal and verbal nature of students' interactions as they participated in inquiry-based science instruction. The results suggest that the use of inquiry-based science investigations afford students opportunities to cultivate science practices that in turn allow for the cultivation of interaction rituals chains specific to those practices that directly affect student participation. Implications arise from these findings that are relevant for both science education research and for science educators.

For science education research, this study shines a light on the embodied, collective nature of student participation. One of the greatest advantages of interaction ritual analysis as an analytical lens, particularly with language learners, is its ability to reveal the embodied as well as the verbal. Nonverbal interactional facets play a fundamental role in classroom interactions for not only language learners, but for all students and yet their importance is often downplayed or relegated to a supporting role in analysis. This study demonstrates the nuances of how these factors were key in Teo's participation in science investigations, and the classroom languages.

Second, by using interaction ritual analysis to zoom in on interaction on microscales, this research revealed resources employed in interaction on timescales that have not yet been fully explored with language learners in the context of inquiry-oriented science instruction. Specifically, this study contributes to prior understandings regarding social interaction during inquiry-based investigations but deepens this understanding by illuminating small-scaled interactional facets and strategies that led to a language learners' fuller participation.

Additionally, this work contributes to a body of research that underscores the value of analyzing student engagement in science as a socially situated collective engagement (Bellocchi, 2017; Elmesky, 2015; Olitsky, 2017; Olitsky & Milne, 2012). The results of this study further support the view argued by Olitsky and Milne (2012) that "participation is an outcome of collective emotion generated in interaction rituals" (p. 18). This pushes back at research and views of classrooms that assign learning to the individual and instead views the embodied, emotional, and cognitive aspects of students' as unfolding in collective interaction and as fundamental to individual students' participation in science learning.

Finally, this study has broader implications for science education research in that it presents interactional views of language. This supports a theoretical move from viewing language as an object to viewing language in interaction and participation. This parallels views of language in interaction widely used in sociolinguistics research, but less seldom employed in current science education research. This shift has pertinent and important implications for the future analysis of language use in science classrooms in that it recognizes and highlights the embodied ways in which people communicate and allows for examining the ways in which language, and science, emerge and evolve in interaction.

For teachers, the findings demonstrate that student-directed science investigations can provide space for flexible communicative resource use and participation. Teo was afforded opportunities to participate through different forms of instructional and social support, and through these varied approaches he was able to experience success using the language he was working to master. This points to structures teachers can use to support student-directed science investigations to provide opportunities for the development of successful interaction rituals and positive emotional outcomes for all students. It additionally demonstrates how spaces can be made through inquiry-based instructional

approaches to facilitate student participation through the use of flexible and varied communicative resources, especially when students are positioned to learn and engage in science through languages they are working to master. Additionally, this study furthers prior research examining interaction rituals in science classrooms in that it shows that if teachers become attuned to the interaction rituals and interaction ritual chains, be they positive or negative, they can work to adjust their teaching practices in ways that lead to increased student participation in general and for language learners in particular.

Through an analysis of interaction rituals that formed among plurilingual students and teachers we shine light on the importance of understanding how students interact in ways that are not always conscious, nor verbal, but that nevertheless have a direct impact on their participation. This understanding is key for supporting the participation of not just language learners, but for all students, in that the forms of instruction used can mediate students' language use and have a direct effect on their participation in science instructional activities.

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ENDNOTES

¹ The term plurilingual is used to describe students who possess diverse language repertoires that consist of various combinations of national languages and communicative resources. The term multilingual is used to describe spaces of varied language use (Council of Europe, 2001). This builds from prior science education research that employs concepts for students working in languages they are learning such as multilingual students, language learners, English language learners, etc. We further theorize this conceptualization of plurilingual students in later sections.

² All participants have been assigned pseudonyms to maintain anonymity.

³ Transcription Key:

|| overlapping talk

... pause

xxx unintelligible speech

:: stretched out sound

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