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Understanding Interactions in Multilingual Science Classrooms through Cultural-Historical Activity Theory (CHAT): What Do Contradictions Tell Us?

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Abstract

Interactions in multilingual science classrooms involve local cognitive and sociocultural dimensions along with global contextual aspects such as language-in-education policies. The intersection of these has implications for providing quality science education and supporting diverse students. This study investigates interactions in Lebanese multilingual science classrooms by using an integrative framework to analyze dialogicity of *local* classroom practices, or the extent to which students' ideas are acknowledged and built upon for conceptual learning. Cultural Historical Activity Theory (CHAT) is then used to depict local practices within the larger *global* contextual aspects. Data were collected through instrumental case studies of three middle school science teachers in schools of different socioeconomic levels. Data sources included: (a) videotaped science lessons, (b) teacher and school leader interviews, and (c) student group interviews. Data were then arranged into an activity system for each teacher's classroom. Each activity system showed how local interactions and practices were situated within contextual aspects and the emergent contradictions in each. We discuss what contradictions tell us about interactions in Lebanese multilingual science classrooms and how these can inform professional development in multilingual science education.

Keywords CHAT · Activity theory · Dialogism · Professional development · Multilingual science education

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Introduction

A sociocultural perspective stresses classroom interactions as shaping the social and academic life of classrooms (Aguiar, Mortimer & Scott, 2010). Within multilingual classrooms, as in the case of Lebanon and several Middle East and North Africa (MENA) and EU countries, teacher talk and ways different languages (e.g., home, international, and dominant) are deployed can be especially important for supporting conceptual and meaningful science learning (e.g., García & Lin, 2016; Jakobson & Axelsson, 2017; Lee & Buxton, 2013; Salloum & BouJaoude, 2019a, 2019b;). The Lebanese educational system is trilingual based on a language-in-education policy that requires that Arabic and English or French be introduced in the first grade and that mathematics and science be taught in the foreign language (English or French). A persistent concern in such multilingual settings is the disparity of students' science performance based on language proficiency levels, whereby poor proficiency in the language of instruction leads to poor achievement in science (Probyn, 2015). Such disparity has been referred to as linguistic discrimination or "linguistically structured inequalities" as it mostly affects students from lower socioeconomic strata (McCarty, Collins & Hopson, 2011; Shuyab, 2016). For example, the frequency of speaking the language of the test at home has been found to influence students' performance in Trends in International Mathematics and Science Study (TIMSS) (Prinsloo & Harvey, 2018; Younes, Salloum & Antoun, 2019;). To understand better such inequalities, classroom interactions need to be investigated both as "a local process and a global one" (Erickson, 2004, p. 107). Accordingly, research needs to examine local classroom teaching and language practices and their conduciveness to quality science learning *and* scrutinize schools as complex activity systems with possible contextual and situational system-level inequities that lead to linguistic discrimination (e.g., how language-in-education policies are implemented and the leveraging of the home language).

Purpose

The purpose of this study is to investigate local and global dimensions of interactions within Lebanese multilingual science classrooms by using an integrative analytical framework that considers *local* classroom and language practices *and global* contextual and cultural aspects. The framework incorporates two related perspectives: Bakhtin's (Bakhtin, 1981) dialogic perspective for analyzing local practices and Cultural Historical Activity Theory (CHAT) to situate local aspects within global ones (Engeström, 2001; Engeström & Sannino, 2010). A dialogic perspective to science teaching involves using dialogic interactions that diverge from a "monolog" or an authoritative one-way transmission model of learning to a multidirectional dialog, where students share ideas with the teacher and with each other to develop collective deeper understandings (Aguiar & Mortimer, 2013; Ford & Wargo, 2011): dialogicity of classroom practices entails the extent to which students' ideas are acknowledged and built upon as they construct scientific understandings. CHAT perceives human activity (e.g., science teaching and learning) as collective (as compared with individual), purposeful, goal directed, and socially organized. Thus, CHAT depicts an activity as a system that is situated within the broad historical-cultural-social contexts. Furthermore, CHAT unravels tensions and contradictions within such systems. By utilizing these two perspectives, our integrative analytical framework sets the foundations for analyzing classroom interactions at different levels. First, dialogicity of local classroom practices are discerned, then multilingual science classrooms are represented as complex activity systems in which local interactions are situated within contextual global aspects, thus providing opportunities to disclose possible contradictions in each. The following research questions were addressed:

1. What levels of dialogicity and conceptual learning emerge in teachers' and students' language and pedagogical practices in different multilingual science classrooms?
2. How are teachers' and students' language and pedagogical practices situated in the classroom activity systems in different multilingual science classrooms?
3. What contradictions emerge within the activity systems of the different multilingual science classrooms and what do these involve?

Dialogic Perspective to Science Education

Interactions in Multilingual Classrooms

A dialogic perspective in science education maintains that meaningful understanding of scientific ideas and concepts requires *dialogic interactions* among students' everyday ways of thinking and talking and the canonical or accepted scientific views (Aguiar & Mortimer, 2013; Mortimer & Scott, 2003). Dialogicity of local classroom interactions draws on Bakhtin's (1981, 1986) distinction between dialogic and monologic interactions or internally persuasive discourse and authoritarian discourse. Internally persuasive discourse is half-ours and half-someone else's; it is personal, creative, productive, and interactive. In contrast, authoritarian discourse is binding and authority-infused, demanding our acknowledgement, even as it may not persuade us internally; the canonical scientific view can be seen as such authoritarian discourse (Scott, Mortimer & Aguiar, 2006).

What would dialogicity look like in the science classroom? Dialogicity involves a multidirectional internally persuasive discourse, where, rather than lecturing, the teacher talks invitingly to students and opens spaces to bridge their everyday ways of knowing with accepted scientific views (Aguiar & Mortimer, 2013; Ford & Wargo, 2011). Both a dialogic perspective and Vygotsky's sociocultural perspective view language as a major mediating artifact and cultural tool in science and science classrooms (Aguiar et al., 2010; Lemke, 2001), where language serves as a system for transmitting information and as an interpretative system for making a sense of experience and co-construction of meanings (Sutton, 1996).

Science Education in Multilingual Settings

The role of language is even more prominent and complex in multilingual science settings with persistent concerns over the influence of language proficiency on linguistically diverse students' science performance (Jakobson & Axelsson, 2017; Lee & Buxton, 2013; Prinsloo

& Harvey, 2018). Such students face the demands and challenges of learning academic content and specialized discipline-specific terminology through an un-mastered language (Garza, Huerta, Spies, Lara-Alecio, Irby & Tong, 2018; Jakobson & Axelsson, 2017; Lin & Yi Lo, 2017), oftentimes with little instructional support and without full deployment of their language and communicative repertoires (García, 2009; Moore, Evnitskaya & Ramos-de Robles, 2018; Salloum & BouJaoude, 2019b). Moreover, linguistically diverse students are often unaware of the expectations for navigating and bridging everyday, disciplinary, and academic languages to accomplish science tasks (e.g., Lan & de Oliveira, 2019), nor are most science teachers aware of the language demands of science beyond discrete terminology (Seah & Silver, 2018).

Science teachers need to enable language learners in developing academic content and processes, while also developing proficiency in the international or dominant language (Lee, Llosa, Grapin, Haas & Goggins, 2019). Research on quality science education in multilingual settings has identified relevant linguistic scaffolds and "bridges" for learners to construct content knowledge and process and build language skills. These include recasting students' everyday talk into scientific talk (Gibbons, 2003), talking, modeling, using bodily action, and practical equipment (Jakobson & Axelsson, 2017); using pauses, gazes, gestures, pointing, and prompts (Zhang, 2016); hands-on inquiry learning (Lee et al., 2019), generative and dialogic talk, and visualizations (Ryoo & Bedell, 2019). Particularly, quality science teaching and learning for linguistically diverse students requires integration of content and language (Lee et al., 2019; Lee & Buxton, 2013; Moore et al., 2018). Instructional strategies for successful integration of science and language proficiency for language learners include incorporating literacy and discourse strategies and diverse participation modes into science classrooms and home culture and language support and connections (Karlsson, Larsson & Jakobsson, 2020; Lee & Buxton, 2013).

Authoritarian Discourses in Multilingual Science Classrooms

Despite the value of the abovementioned strategies for bridging students' everyday understandings with the authoritarian canonical science; how teachers learn and adapt them needs to be understood within the broader sociocultural and sociopolitical context. In multilingual science classrooms, additional forms of authoritarian discourse emerge: the government-imposed language-in-education policies or medium of instruction and the language of national high stakes tests (Salloum & BouJaoude, 2019a, b). For example, authoritarian discourse of language-in-education policies intertwines with socioeconomic power structures in a society, influencing schooling, cultural and national identities, and how *communities* value their home language (Creese & Blackledge, 2015). Proficiency in an international language does provide access to the dominant discourses of a scientific and technological world (Orr & Annous, 2018), but cultural or identity conflicts can affect linguistically diverse students' science performance negatively (Lee & Buxton, 2011).

According to Bakhtin (1981), interactions in multilingual classrooms, or teachers and students' internal persuasive discourse, occur within different authoritarian discourses (e.g., language-in-education policy and canonical scientific knowledge) and other sociocultural, socio-economic, and socio-ideological aspects. These discourses intersect with each other in a variety of ways and form new socially typifying "languages" that represent "the co-existence of socio-ideological contradictions between the present and the past, between differing epochs of the past, between different socio-ideological groups in the present, between tendencies, schools, circles and so forth, all given a bodily form" (Bakhtin, 1981, p. 291). Socially typifying language that emerges in science classrooms would entail different pedagogies and forms of learning (Salloum & BouJaoude, 2019a). Ritva Engeström (1995) suggested that socially typifying languages, such as interactions in multilingual classrooms, correspond to the level of collective activity and so can be analyzed as activity systems or complex and socially situated activities (Engeström, 2001). Hence, CHAT was integrated with a Bakhtinian perspective as an analytical framework that situates local science classroom interactions within global contextual and cultural aspects of multilingual classrooms (e.g., larger educational system and society).

CHAT: An Activity System Perspective on Classroom Interactions

Engeström (1999) developed what has been termed the second-generation CHAT system to describe socially organized collective human activity in the broad historical-cultural-social contexts. Engeström (1999) identified the following elements of the activity system (Fig. 1): (a) The *object* is the problem space targeted by the activity and this goal-object is transformed into *outcomes*; (b) the *subject* is the individual or a group (collective activity) who seeks to direct the activity towards the object; (c) *instruments* or *mediating artifacts* are cultural products utilized by the subject and *community* to target the object, mediating artifacts can be physical and symbolic, external and internal tools and signs such as language (hence relevance of CHAT for characterizing classroom interactions); (d) the *community* represents those individuals who share the same general object of the activity and define themselves as distinct from other communities; (e) *rules* are the explicit and implicit regulations, norms, and conventions that regulate and control actions and interactions within the activity; and finally, (f) *division of labor* refers to division of tasks between members of the community and the division of power and authority within the activity.

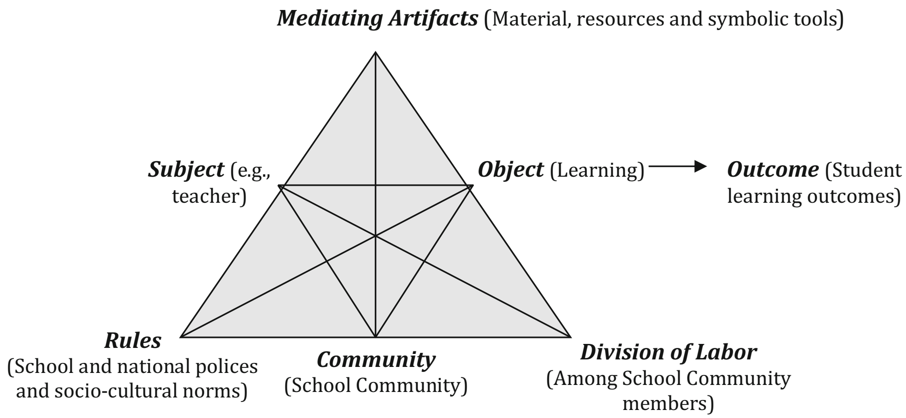


Fig. 1 The classroom as an activity system

A science classroom as an activity system involves certain types of student learning as an object, such object in turn transforms into a context-based *outcome*. Engeström (1999) introduced the notion of *expansive cycle or learning* as a qualitative transformation of the activity system as a whole: an expansive cycle starts from a contradiction between the different elements of the activity system. Change starts at the individual level through the processes of internalization–externalization experienced by the subject engaged in activities, which can lead to either adherence or transformation of knowledge acquired by society (Leont'ev, 1978). The successful orchestration of the individual activities will be an expansive cycle that eventually transforms the system into one that is free of the contradiction that started it. The transformed system may now have different outcomes, relations, and interactions among its elements. CHAT, as a transformative framework (Roth, Lee & Hsu, 2009), is being increasingly utilized in science education to examine diverse communicative tools as mediators of teaching and learning (Martínez-Álvarez, 2019); to illuminate normally invisible and naturalized processes and interactions (Stroupe, Caballero & White, 2018; Vieira & Kelly, 2014); and to explore and compare larger system issues and the influence of contextual factors on science educators' professional learning and enactment of reform-minded pedagogies. Particularly, CHAT helps us better understand the contradictions (e.g., tensions) in educators' development and practice that contribute to adherence and ones that facilitate transformation and expansive learning of the individual and system (e.g., Goodnough, 2018; Saka, Southerland & Brooks, 2009).

Second-generation CHAT was developed into third-generation CHAT that examines networks of interacting systems to address the contradictions that promote expansive learning (Engeström, 2001), where different activity systems and their contradictions can be compared for informed effective action (Fig. 2). Different science classrooms would have a general shared object of "student learning" but may display different contradictions. In this research, we explore the mediation tools (e.g., language and strategies for language learners) and system aspects that influence teaching practices and learning of linguistically diverse students. Our integrative framework attempts to illuminate particularities of different multilingual science classrooms and schools and the contradictions distinctive to them. Distinctive contradictions can highlight particular areas of need (e.g., in instruments or division of labor) and inform responsive and effective teacher learning and development activities that counter linguistically structured inequalities.

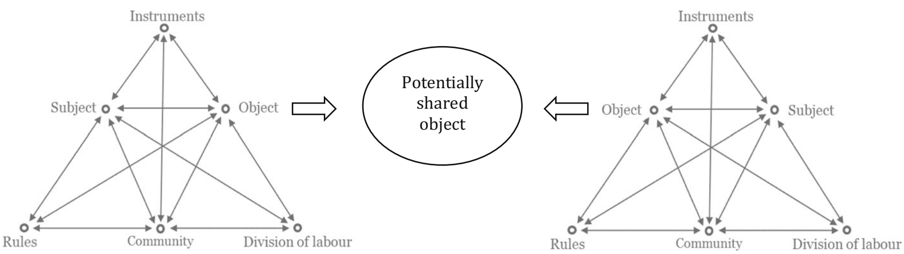


Fig. 2 Representation of the third-generation CHAT

Methods

This study is a part of a larger collective case study, which involves five middle school science teachers in schools of different socio-economic strata (SES) (Creswell & Poth, 2018; Stake, 2013). Three of the instrumental case studies, each as an independent system, were chosen to illustrate language and pedagogical practices in multilingual classrooms through CHAT representations. The case studies were purposefully chosen from different SES schools and because they demonstrated a wide and informative scope of contradictions.

Settings, Schools, and Participants

An important particularity of the Lebanese school system is that schools in Lebanon are trilingual where science is taught and assessed in a foreign language (English or French). Accordingly, the national science textbooks and examinations are also in a foreign language. The medium of instruction of science in this research was English, whereas students' home language is Lebanese colloquial Arabic. Administrators in private and public Lebanese schools encourage science teachers to use the language of instruction and to avoid using the home language, especially in middle school (principals' interviews). Another particularity is that more than 60% of Lebanese students attend private schools (Center for Educational Research and Development [CERD], 2017). Private schools in Lebanon serve diverse SES populations and vary widely in terms of tuition fees, teaching methods, and resources. Lebanese students' performance on international examinations such as TIMSS at the eighth-grade level has been consistently lower than the international average (CERD, 2020). Reports of student performance suggest that teacher-centered approaches used in teaching most subjects and teaching science in a foreign language contribute to these results.

The three participating physical science teachers taught in schools of varying SES levels: an urban public school, an urban private school, and a suburban private school. The urban private school has moderate tuition fees and serves lower middle-class students; the urban public school serves low socio-economic level students, while the suburban private school is an elite school with relatively high tuition fees, thus serving higher middle class and affluent students. The schools of the study were mid-sized, with around 50 students per grade level in two or three sections, and were well respected in the community. The schools' performances as per the percentage of students passing the grade 9 official examinations are as follows: the suburban elite private school, 97.14%; the urban private school, 89.19%; and the urban public school, 62.91%. This study's private schools provide active professional development for their teachers while the public school teachers attend professional development activities in centralized locations managed by CERD.

The teachers were chosen based on recommendations of the schools' principals and their willingness to participate in the research. The teaching experiences of the science teachers ranged between 5 and 15 years. The private schools' physical science teachers were female while in the public school's teacher was male. Each teacher was observed for around 16 periods (2 months) in eighth-grade classrooms (student age 13–14 years), so as to observe a whole instructional unit. A minimum of eight periods were videotaped. We purposefully avoided classes in which students sit for grade nine national examinations because we did not want preparation for the examinations and their language demands to emerge as a prominent issue (see, e.g., Salloum & BouJaoude, 2019a).

Data Sources

Data sources to examine teachers' and students' language practices (dialogicity and conceptual learning) were classroom observations and videotaped science lessons (24 transcripts). Participants' meaning making of language practices and language policies were explored through semi-structured interviews: individual interviews with the three teachers and three school leaders, and three-student group interviews (6–15 students/per group). The interviews were conducted around the end of the fieldwork using interview protocols (included in the Supplemental Materials) developed to explore participants' perceptions about teaching and learning science in English. Teachers and leaders' interviews were audiotaped and student interviews were video recorded. Interviews lasted between 35 and 50 min long and were transcribed. Other data sources included classroom instructional materials and informal conversations with teachers and administrators around teaching and learning science in a foreign language.

Data Analysis

Engeström (2001) proposed the activity systems as a schematic and structural model to describe and organize series of practices. We considered the science teachers subjects, and we needed to create representative activity systems for each. The different data sources were used to discern themes that inform the activity systems' various elements: *instruments*, *object*, *rules*, *community*, division of labor, and *outcome*. We describe below our data analysis and how it informed our construction of the activity systems.

Classroom Observations. Classroom interaction transcripts of teacher and student utterances were analyzed using a modified version of Mortimer and Scott's (2003) framework, with aspects of analysis being: *content*, *discourse pattern*, *teacher intervention*, *communicative approach*, and *teaching purpose* (Table 1). The aspects were modified to depict possible influences of language use on conceptual learning (Salloum & BouJaoude, 2019b).

Table 1 Modified Mortimer and Scott (2003) framework of the five linked aspects of classroom and teacher talk

i. Focus	1. Teaching purpose The purpose of science lessons manifested through practices and interactions	2. Content Interactions analyzed based on knowledge types presented and supported and ways participants deployed home and international language
ii. Approach	1. Communicative approach Dialogic/interactive—dialogic/non-interactive Authoritarian/interactive—authoritarian/non-interaction	
iii. Action	4. Patterns of discourse Patterns of interactions in science classroom and language deployment	5. Teacher intervention Strategies teachers used as scaffolds and linguistics bridges for conceptual understanding

First, codes were generated for the aspects of content and discourse pattern, as these address our first research question on dialogicity and conceptual learning (codes with descriptions included in the Supplemental Materials). Content of classroom interactions were analyzed and coded based on knowledge types promoted in classroom interactions, with the types being: factual, conceptual, and algorithmic along with frequencies of each (Anderson & Krathwohl, 2001; Salloum & BouJaoude, 2019b). We also coded how and when home and English were used to explain and review science concepts and the knowledge types that resulted from such usage (Salloum & BouJaoude, 2019b). *Discourse patterns*, especially in large group instruction, tend to consist predominantly of triadic dialog or Initiation (a question usually posed by the teacher), Response (usually by student), and Follow-up (by teacher or students). Such dialog is labeled as IRF and/or IRF chains (Mortimer & Scott, 2003; Salloum & BouJaoude, 2019a, b). Interactions were coded for how open or "inviting" IRF and IRF chains were and for how and when home language (Colloquial Arabic) and English were deployed within IRF and IRF chains. To enhance reliability of coding, the two researchers watched two videotaped sessions of different teachers and coded together the classroom transcripts by discussing their first impressions in terms of science knowledge types, discourse patterns, and language deployment that characterized classroom interactions. Then the two researchers analyzed and coded two different transcripts independently to further solidify knowledge type and discourse pattern codes. The results were then shared and differences in analyses discussed until consensus and agreement were reached. The remaining 20 transcripts were coded accordingly by the first author.

Second, the two researchers examined the coded transcripts separately and noted frequencies and patterns to extract themes around content, discourse pattern, and teacher interventions for the different teachers/subjects. These themes were shared and the two authors discussed them and checked for confirming and disconfirming evidence in coded transcripts as a form of "cross check" between the two researchers. This process was used to ensure validity of the findings. Following this cross check, and based on the agreed-upon themes, we collectively delineated assertions around the extent to which *communicative approaches* in the classrooms seemed authoritative (highly teacher-directed) vs. dialogic and interactive vs. non-interactive (level of student participation). Similarly, the *teaching purpose* was deduced from content, pattern of discourse, and communicative approach.

Teacher interventions were analyzed deductively to document teachers' use of strategies that support conceptual learning of linguistically diverse learners in science, e.g., home language support, multi-modal teaching (e.g., hands-on, multiple representations), and literacy strategies (Lee et al., 2019). Finally, and through a dialectic and iterative process, we discussed and arranged results from observation data into the different elements of a classroom's activity system: Teacher interventions, such as language deployment and scaffolds, group work, and use of demonstrations, along with discourse patterns informed "instruments" and "mediating artifacts." Content promoted, communicative approaches and teaching purpose informed the *object* and *outcome* of the system. Detailed observation analyses for two of the schools are presented in Salloum and BouJaoude (2019b).

Interview Analysis. CHAT examines, not only how purposeful human activities function in the world, but also how individuals make meaning through social, cultural and historical contexts (Postholm, 2014). Therefore, participants' interviews were examined for how participants gave meanings to the language-in-education policy and classroom practices. Teachers' and students' statements were condensed under the concepts below:

- Classroom practices associated with teaching science in English.
- Teachers' and students' perceptions of advantages and disadvantages of teaching science in English and its impact on learning.
- Teachers' and students' perceptions of school-wide policies and practices related to teaching science in English and the language-in-education policy

Emergent themes were extracted within each of the above concepts across the three contexts. Teachers' and students' perspectives informed the CHAT elements of *object*, *division of labor*, *community*, *rules*, and *outcomes*. Interviews with the school leaders were analyzed similarly with special emphasis on possible influence of school-wide policies on language deployment. The leaders' perspectives informed *division of labor*, *community,* and *rules.*

Second- and Third-Generation Activity Systems

As mentioned above, constructing the activity system required multiple readings and discussions of the findings from observations and interviews. Once the three systems were constructed, a final step involved identifying areas of contradiction and congruence in each context. Contradictions were identified when participants expressed challenges and difficulties towards reaching the object and outcome; when participants expressed contrasting views; and when we, as researchers, identified challenges and obstacles towards conceptual learning in science as an outcome. In the "Discussion of Findings" section, we extend the analyses to compare the three activity systems.

Findings

Research Question 1: Dialogicity and Conceptual Learning in the Classrooms

Content Interactions in the private schools of this study consisted mostly of *factual* content and instructions on how to apply algorithms. Transcript 1 from the private urban school exemplifies a typical interaction in the private schools (Table 2). During this interaction, the teacher wanted students to practice writing formulas of ionic compounds through whole class work. Bold words indicate the use of home language, translation in brackets. In statement 6, the teacher summarizes the general rule or algorithm of the "crisscross" method (the absolute value of the cation charge becomes the subscript of the anion and vice versa in an ionic compound). The classroom interaction involved applying the algorithm, with almost no reference to the concept underlying it (e.g., octet rule); please see italicized text in statements 3, 6 and 16. In statement 3, students are reminded of the need for two oppositely charges ions to make an ionic compound without reference to role of valence electrons. Again, in statement

Table 2 Transcript 1 from eighth-grade chemistry class in the private urban school

Classroom interactions	Discourse pattern
1. Teacher: So we have to give the formula of the ionic compounds and then name them. Ok? Yes, Amal (student pseudonym)?	Directive
2. Amal: (…)	Student initiation
3. Teacher: *Cation and Cation do not make an ionic compound that's what I said to you before. There must be opposite charges. There must be a cation and an anion. Ok*? (…) huh? Yes.	Teacher response
4. Teacher: So this one is for Faten (student pseudonym). What do we do?	Initiation 1
5. Student: **Ya3ni** [meaning] ... Ca and Cl … in Ca minus and Cl^{2+}.	Response
6. Teacher: Listen. *In ionic compounds, we do not have any charges. Ok? So the positive and the negative will cancel each other and then disappear*. Ok? Now ... *So*, *what is the crisscross method*? (On the board, the teacher connects Ca to the 1^- of the Cl, and Cl to the 2^+ of the Ca) *Ok? The two will go to the Cl atom and the one to the Ca but we do not write one*. So, what is the formula?	Follow-up: Elaboration
7. Student: $CaCl_2$	Response
8. Teacher: $CaCl_2$. Ok? $CaCl_2$. That's it.	Follow-up: Evaluation
9. Another one?	Initiation 2
10. Student: give the ...?	Response
11. Teacher: The formula ...	
12. Student: **la** [for]	
13. Teacher: give their name	Initiation 3
14. Student: Fe $^{3+}$ emm S^{2-} **Ya3ni Miss btseer** Fe–Fe_2S_3 [Meaning "Miss' that it becomes Fe–Fe_2S_3]	
15. Teacher: So, that's it. This is the crisscross method	Follow-up: Evaluation
So, Fe_2S_3 (…) so who can give me the name of those compounds?	Initiation 4
…	
16. Teacher: Calcium Chloride. So, we just write the name of the cation then the anion.	Follow-up: Elaboration

6, the algorithm is summarized, "The two will go to the Cl atom and the one to the Ca but we don't write one," with no reference to why subscripts form this way and the concept of electrons being lost and gained.

In the public school, even though there was still some dominance of factual content, utterances included more conceptual and sophisticated ones and interestingly, when utterances were conceptual rather than factual, students responded in the home language to explain themselves. In transcript 2 (Table 3), the science teacher used blue and red pen caps to represent protons and electrons and explain how ionic charges from. He held an equal number of same-colored caps in each hand when the interaction started. The italicized text in the teacher's statements numbered 4, 6, and 8 demonstrates how the teacher was trying to explain conceptually why ions have a charge by using the pen caps and drawing on the board. In statement 4, the teacher tries to extend understanding by asking students which subatomic particle will "go" to make the atom a charged ion (initiation 2), and then in line 6, he continues the chain with a follow-up "why?" In

Table 3 Transcript 2 from eighth-grade chemistry class in the public urban school

Classroom interactions	Discourse pattern
1. T: They are equal. **Hal fiyye oul fee shee aktar min shee**? [They are equal. Can I say one is more than the other?]	Initiation 1
2. S1: No!	Response
3. T: No. They are equal. **Fa houl el zuru2 hinne** protons **wil** red **hinneh** electrons. **Shou el charge lal** atom? Is nul. Zero. They cancel each others. OK? [they are equal. These blue are the protons and the red the electrons. What is the charge of the atom? Is null. Zero …] Now. Look here. We have five and five. If they differ from each others, **7a yeseer fee 3andi** charge. **Mashi el 7al? 7a yeseer 3andee** charge, **7a yikhtillif el** number, **byebatel** zero, **byebatlo ya3mlo** cancel **la** each other. [Now. Look here. We have five and five. If they differ from each other, we will a charge. You follow? We will have a charge, the number will be different than zero, they no longer cancel each other.	Follow-up: Elaboration
4. Teacher: **Bas meen ra7 yeroo7? El** protons **willa el** electrons? [*But what will go away the protons or the electrons*?]	Initiation 2
5. S2: **el** electrons?	Response
6. T: **laish** [*Why*]?	Follow-up: Feedback
7. S2: **Istaiz**, **7assab el** atom ... **7assab el** element [sir, depends on the atom … depends on the element]	Response
8. T: **Meen ra7 yeroo7? El** protons **willa el** electrons? **Hait tanshouf tanraje3 ... Khaleena inraje3 shway bil atoms**. (teacher draws on board) **Khaleena nerssum el** atom. **Hay el** nucleus **ta3eeta, fi bi alba** protons. **Eh? Uuuuh. Be alba** protons **ou be alba** neutrons. **Tayeb. 3andee 3al** electron clouds. **3andee** electrons. [*What will go? The electrons or protons? Let us see. Let us draw the atom. This is the nucleus and it has the protons and has the neutrons. Ok. I have the electron cloud. I have electrons*].	Follow-up: Elaboration
9. S3: **byedalo byiliffo 7awaleya** [*They keep on moving around it*]	Student Elaboration
10. T: **mashee el 7al? Le** protons **ad el** electrons. Five and five. **Fee 3anda charge lakain?** [Ok, the protons are equal to the electrons. Five and five. Does it have a charge then?]	Initiation 3
11. S (many): no, nul	Response
12. T: Five positive, five negative?	
13. S (many): nul	
14. T: Nul. if one of these electrons ...	
15. S (many): **Ra7** [goes away]	
16. T: **Ra7** ... (teacher erases electron off electronic cloud)	
17. S: **byeseer fee charge positive** [*There will be a positive charge*]	

statement 8, and noting students' confusion in statement 7, the teacher does not give the answer, he draws the atomic model on the board and reviews the subatomic particles. In statements 9 and 17, students respond in Arabic to show that they are following the teachers' follow-up on how electron loss and gain creates a charged ion (statements 8 and 10).

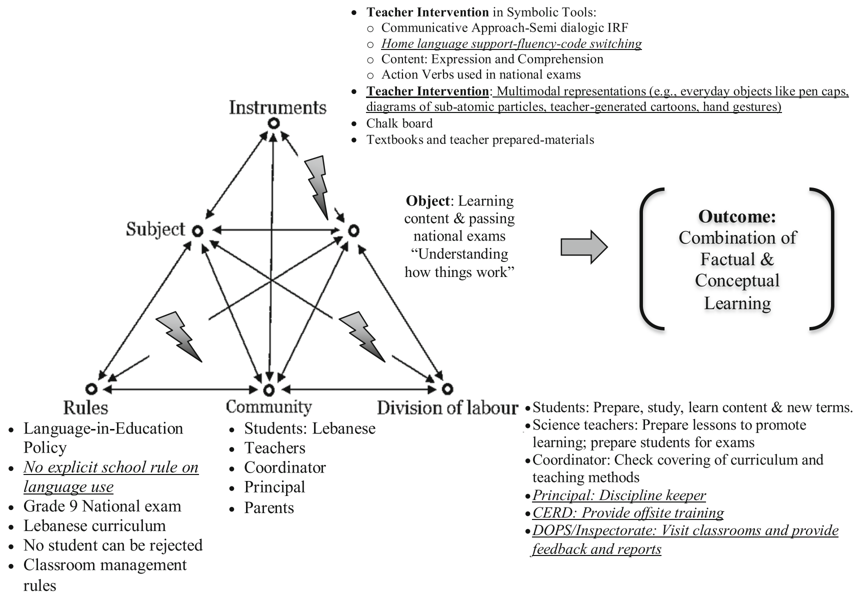
Patterns of Discourse and Communicative Approach Initiation, response, and follow-up (IRF) and IRF chains were the prevalent discourse pattern observed across contexts.

In the private schools, the teachers use English almost all the time, mainly due to most private schools' policy of using the foreign language in the science periods (principal interviews). In the lower SES private school, students' responses in English were mostly to give shorter factual answers, and they oftentimes used Arabic to inquire and explain. For example, in transcript 1, the student responded with "$CaCl_2$" in statement 7, when another student tried to show how they used the crisscross method, she infused Arabic in statement 14 "Fe $^{3+}$ emm S^{2-} **Ya3ni Miss btseer** Fe – Fe_2S_3 [so Miss'it becomes Fe – Fe_2S_3]." In the elite school, classroom interactions followed mostly a purposeful IRF discourse pattern with initiation questions from the teacher in English, student response also in English, and teacher evaluation. In the elite school, teacher talk was more than twice the student talk, comprising 67 to 73% of classroom interactions. Teacher talk dropped to 67% when students were solving exercises and were *required* to give longer answers. In other lessons, teacher talk involved the teacher explaining with only short and direct comments from students and rare students' questions. Students responded mostly with one word answers including "fine, okay, yes, and no." A school policy in the private schools restricting language deployment to English coupled with less teacher "invitations," with "why" questions for example, indicated limited dialogicity and a dominance of factual and surface learning. Thus, a communicative approach of authoritarian/interactive emerged strongly in both private schools: the teacher leads students through a series of purposeful questions and answers to attain scientific knowledge in English. Actually, in the elite school, the communicative approach was almost authoritarian/non-interactive. In the public school, even though the communicative approach was also mostly authoritarian/ interactive, home language was used more fluently as a mediating tool for promoting more conceptual and sophisticated learning; as such higher dialogicity was noted as we saw above with the teacher using IRF chains and "why" follow-ups for students to "find out" which subatomic particle "goes away." Condensations of observation and interview data are tabulated in supplemental materials.

Research Questions 2 and 3: Situating Practices in Activity Systems

We outline activity systems below for the three science teachers' classrooms to demonstrate how teachers' and students' language and pedagogical practices were situated and played out in the different multilingual classroom systems. Contradictions among elements are marked with a "lighting arrow" and a corresponding table explains the contradictions below each activity system. Illustrative data were also included in the contradictions tables: "Obs" indicates observation data, "P-Int," "T-Int," and "S-Int" indicate data from principal, teacher, and student interviews. The underlined text in italics within activity systems marks notable differences among context (e.g., public, private, etc.). Figure 3 depicts the urban public school classroom's activity system with the physical science teacher as the subject; Fig. 4, the urban private school classroom, and Fig. 5, the elite suburban private school.

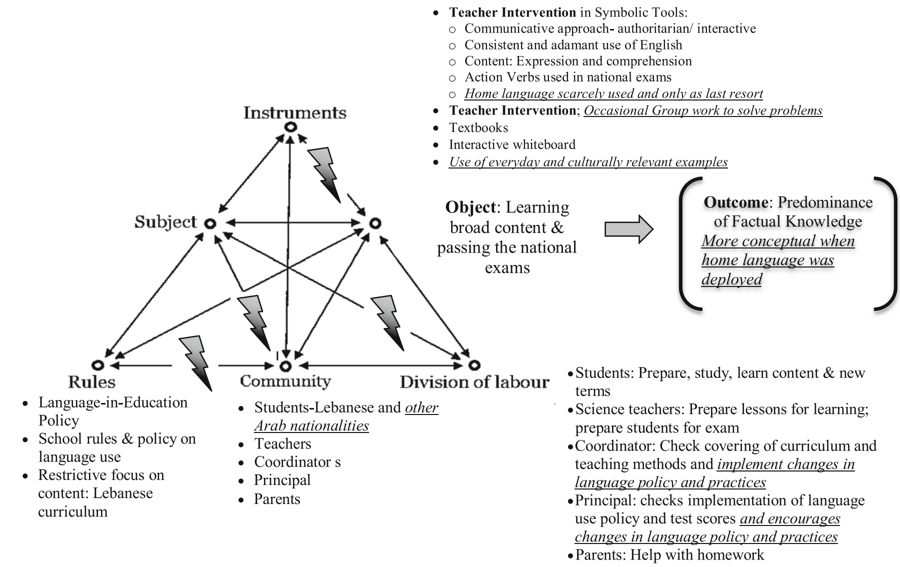
Activity systems of the different science classrooms outline how local interactions and practices were situated within the activity systems and the contradictions that emerged. A shared outcome was learning and covering material for passing the national examinations (in the urban public and private school) and extended to getting good



Contradiction Areas	Aspects of Contradictions	Connection to Data
Subject-Division of labor	• Lack of systematic and purposeful training of teacher (subject) on integrated content and language approach and active literacy in content (subject-CERD) even as the need is acknowledged	Teacher expressed concerns about the effect of language proficiency on learning and exam performance [T-Int] Science teachers receive mixed messages about using or not using home language in instruction from school administrators and state supervisors and inspectors. [T-Int; P-Int]
Instruments – Object	• Students' limited English proficiency affecting their performance in national assessments and international assessments (TIMSS)	Concerns about students not understanding test items and action verbs in national exams, and them not expressing understanding well due to language issues. [T-Int]
	• Science textbooks are not a useful resource for linguistically diverse students except as a source of practice problems	Teacher complained that textbooks are mostly used for exercises, not as a learning tool
	• Limited resources in public schools for more complex inquiry-based learning	Teacher uses red and blue pen caps to represent charged ions [Obs]

Fig. 3 Urban public school activity system with contradiction areas (physical science)

results in the suburban elite school. In this study's private schools, there was more focus on factual and algorithmic learning needed for passing tests. As such, the authoritarian discourse of preparing students to pass the national examinations emerged strongly with less attempts to bridge English, Arabic, and science discourses as evidenced by less use of scaffolds. In terms of contradictions though, some were similar and others were different. For example, contradictions between the subject and community (students) around use of home language arose in the lower SES private school (Fig. 4), where students as part of the community resented not being able to use their home language as a meaning-making tool or scaffold. This diverged from the elite private school (Fig. 5), where the "English-only" school rule was appropriated by all and so was a point of coherence. In the next section, we discuss and compare contradictions and what they are



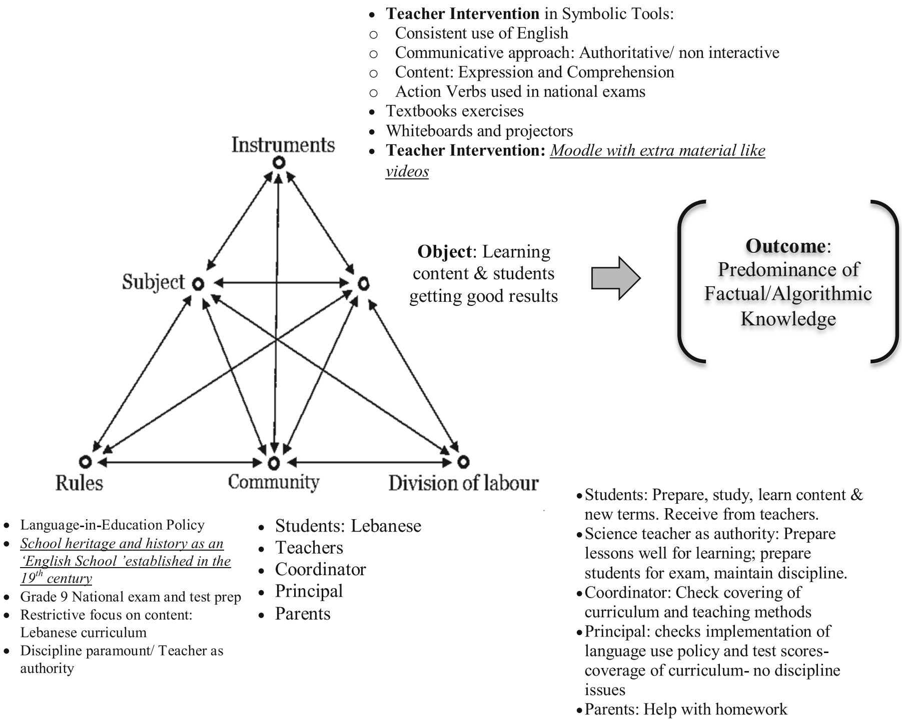
Contradiction Areas	Aspects of Contradictions	Connection to Data
Subject-division of labor	• Lack of systematic and purposeful use of an integrated content and language approach by the teacher (subject) even though the school started encouraging using such an approach	Please see teacher intervention above: There was limited purposeful scaffolds for language learners [Obs]
Subject-Community	• Teachers almost exclusive use of English, students as part of the community respond in the home language, resisting almost exclusive use of English	Students deploy home language (Arabic) to Respond and ask for clarifications, and English mostly to give shorter factual Responses [Obs]
Rules – Community	• Students as part of the community resent the school's policy of "only English" in the classroom, even when they acknowledge the utility of the language-in-education policy for future careers and studies	Students prefer to communicate and ask questions in their home language to better understand science concepts [S-Int]
	• The change in demographics (influx of students from other Arab countries who used to study science in Arabic) led to challenging the strict rule of only English in the science classroom.	Teacher sees using home language as a deficit practice, but acknowledge students' ease in responding in the home language, "one word in home language may help then explain their thinking, which may require them to use two sentences in English" [T-Int]
Instruments – Object	• Use of instruments leading to surface rather than deep content learning • Science textbooks are not a useful resource for linguistically diverse students except as a source of practice problems	Interactive features of the interactive white board were not fully used as scaffold [Obs] Home language not used to scaffold learning, except in extreme confusion cases [Obs]

Fig. 4 Urban private school activity system with contradiction areas (physical science)

telling us about interactions in the Lebanese multilingual science classrooms in particular and quality multilingual science education in general.

Discussion of Findings

Our integrative CHAT-based framework depicts and investigates interactions in multilingual science classrooms as complex systems with interrelated cognitive/academic, socio-cultural, and socio-political dimensions. The framework illuminates



Contradiction Areas	Aspects of Contradictions	Connection to Data
Contradiction areas not evident	Science classrooms highly structured with students mostly focused on the material and solving exercises that follow The teacher displayed high levels of confidence and only occasionally would a student ask a question to go beyond the required material (e.g., concerning a video on the topic) to be redirected to regular and structured class discourse pattern	Teacher expressed that rewards of teaching as "students are participating, *working, their results are good,* they are understanding, it's easy to teach them." When asked about challenges, "*no I am fine*" Teaching science in in English is "*an advantage"* for studying abroad [T-Int]

Fig. 5 Elite private school activity system with contradiction areas (physical science)

contradictions around *dialogicity* or the bridging of students' everyday knowledge and that of canonical science within multilingual classroom interactions, language deployment as sociocultural mediating tools, and levels of conceptual learning as a cognitive/ academic *outcome* of the system. The framework situates these within the broader sociopolitical context of policies and *rules*. Our use of CHAT maps out complex multilayered instructional activities within an integrated system, where language and pedagogical practices in multilingual science classrooms are "interrelated parts of a whole," not detached from their context (Patchen & Smithenry, 2014).

Situational Aspects in Science Teaching and Learning in Multilingual Settings

Our study further illuminates the complexity of situational aspects in multilingual science education (e.g., language-in-education policies, resource availability, etc.) and their interactions with pedagogical practices and outcomes. Our findings show that the flexible deployment of home language supported conceptual learning and promoted dialogicity (Lee et al., 2019). However, such support was not enough to counter system-level contradictions that lead to lower achievement in science (Fig. 3). One such contradiction was that public schools are required to accept all students without identifying and addressing their academic needs and accordingly providing teachers with resources in the form of professional development and *instruments* that can support multimodal science teaching and learning for linguistically diverse students, such as functional laboratories for hands-on student inquiry.

Contradictions within the public school's activity system highlight what Kennedy (2010, p. 591) referred to as "fundamental attribution error," a social psychology concept whereby researchers attribute behaviors to personal qualities and characteristics rather than to situational aspects and influences. She emphasized that promoting quality teaching requires looking at the strong impact of broader teaching situation itself (e.g., the school, the classroom, teachers' schedules, and available resources), "what is needed is a closer examination of the situations that individual teachers experience that may provoke the practices we see in their classrooms" (Kennedy, 2010, p. 593). She, accordingly, outlined work conditions that are likely to affect teachers' effectiveness, such as parameters of the teachers' work (e.g., time, material, work assignments, workplace norms and rules, and workloads), and the students. Such conditions connect closely to different elements of an activity system. For example, within parameters of teachers' work, materials such as textbooks and manuals seem closely related to instruments or mediating artifacts in a classrooms' activity system. In our study, one of the contradictions across schools was the limited role Lebanese science textbooks (instrument) play in engendering deeper learning. Lebanese textbooks are in the foreign language of instruction (English or French) while the home language is Arabic, and include little scaffolds for linguistically diverse students. Teachers in lower SES schools stated that they only use textbooks for exercises rather than as useful resources for students to learn, review, and build science terminology (Figs. 3 and 4). Previous research has revealed that Lebanese chemistry textbooks use very few multiple, hybrid, or mixed representations that support students in developing deeper levels of learning (Shehab & BouJaoude, 2017). Work assignment, or teachers' workload and schedules, can be linked to *division of labor* and how this may affect outcomes. The activity systems depicted above show that *division of labor* across the systems did not support purposeful integration of content and language through collaborations among science and language teachers.

Acknowledging Diverse Students' Needs

Teachers work with developing students rather than adults, and students can have perspectives that diverge largely from those of their teachers and other adults (Kennedy, 2010). In a science classroom's activity system, students' diverse needs and perceptions are strongly highlighted and acknowledged in the elements of *Community* and *Division of Labor*. Stroupe et al. (2018) maintained that CHAT helps to illuminate how educational change and development requires all participants in a community to make active contributions, including diverse students who are usually on the margins. In the private school serving lower middle-class students, a major contradiction was manifested through limited dialogic interactions and students' dissatisfaction with the English-only school *rule* that restricted home language support for learning science (e.g., Lee et al., 2019). In one episode, when the teacher deployed home language with an everyday and culturally relevant example (pickles) to address students' conceptual confusion about acidic properties, student participation and contribution using home language as a mediating *tool* was enhanced (Fig. 4). Therefore, the urban private school teacher's brief challenge of the English-only *rule* using the home language and a culturally relevant everyday example, addressed the contradiction mentioned above with students (*community).* As result, a more dialogic interactions occurred, whereby students' everyday science was bridged with canonical science for deeper conceptual learning (*outcome*) (e.g., Aguiar & Mortimer, 2013). Similar to the teacher in Patchen and Smithenry's (2014) research, who had to navigate shifts in authority to create opportunities for her students to collaborate and inquire, in our study, the teacher facing students' pronounced confusion about the concept (contradiction) had also to navigate CHAT elements to resolve the confusion (e.g., briefly challenging the English-only *rule* and deploying home language as an instrument). In that instant, the teacher brought in students, who are usually at the margins of the community, and opened up spaces for participation (Stroupe et al., 2018).

Third-Generation CHAT: Comparisons Among Classroom Systems

More resources were available for science teachers in the private schools (e.g., interactive whiteboard and scientific apparatus), yet a contradiction that emerged in this study's private schools was that these *instruments* were not used to their full potential as mediating tools or scaffolds for deeper conceptual learning in science (as opposed to surface learning), nor for particularly supporting linguistically diverse students (e.g., limited use of active multimodal teaching methods that entails multiple representations, visualizations, and hands-on work, please see Fig. 4). In the lower SES private school, this contradiction took shape in students' more frequent requests for clarification, mostly in their home language. Interestingly, in the elite private school, such an internal contradiction did not emerge explicitly (Fig. 5): students' requests for clarification were less frequent with an apparent acceptance of an authoritative communicative approach or a highly teacher-directed pedagogical approach. Earlier research has shown that students and teachers in selective private schools prioritize high test scores for getting into selective majors at elite universities (Salloum & Abd-El-Khalick, 2010). A focus on test scores as a vehicle to desired selective tracks in schools and university majors promotes acceptance of a restrictive focus on science content by the community including students (and their parents). A second situational aspect that may have contributed to internal coherence in the elite school was students' high English proficiency level and so the foreign language did not pose a barrier for comprehension and expression (e.g., Larsson & Jakobsson, 2020). In the elite school, multiple authoritarian discourses seemed to be assumed by the community: the hegemony of a "content" focus of mandated curricula, national examinations that mainly test factual knowledge, and language-in-education policies that also reflect the school's history as a nineteenth-century school established by English missionaries. According to Bourdieu and Passeron (1977), schools are arenas for the reproduction of social classes and so such appropriation of authoritarian discourses may manifest how cultural capital is instilled, familiarized, and transmitted in the higher-class home to advantage children in a competitive educational system. Particularly, language-in-education policies in Lebanese multilingual classrooms can contribute significantly to either widening or narrowing the gaps among different groups in society by contributing for example, to linguistically structured inequalities (Probyn, 2015).

Vieira and Kelly (2014) suggested that a CHAT-inspired analysis could help teachers understand and critically reflect on how articulations of different discourses in society can affect their discursive practices in teaching science. They claimed that the effect of authoritarian discourses might seem "natural" and "necessary" to teachers, thus contributing to the reproduction of the status quo. To affect changes in teaching practices, teachers need to become aware and critically reflect on how individual goals (action level) are adapted to satisfy more significant motives (activity level), thus "denaturalizing" existing practices and exploring more equitable alternatives. In the case of the elite school, however, authoritarian discourses such as ones mentioned above work well for students' trajectories towards higher education and as such, practitioners may not see the value of questioning them.

Alternatively, contradictions in the urban private school highlighted the teachers' 'felt difficulties' and challenges in responding to students' with diverse language needs (e.g., limited awareness of strategies such as multimodal teaching, home culture connections, home language support, content and language integrated approaches, etc.). The teachers explicitly mentioned concerns about students' English proficiency's effect on science performance; either due to students not comprehending questions or them not being able to adequately express their (sound) thinking and reasoning in the foreign language. Contradictions connected to teachers' felt difficulties in themselves did not, however, automatically initiate expansive learning and sequences of learning actions (Engeström & Sannino, 2010). Rather in the private urban school, it was change in the schools' population and an influx of monolingual Arabic students from neighboring countries that played a role in inviting the beginnings of expansive learning (Fig. 4). The "rule" of English only was challenged and changes in "division of labor" were initiated with the administration encouraging collaboration among science and language teachers to serve the needs of new students (community). Accordingly, small innovative expansive cycles occurred through adopting new "instruments" for better outcomes, for example teachers were allowed to use home language support in the classroom and translate science test items to the new students.

Conclusion and Implication for Teacher Learning in Multilingual Science Classrooms

A CHAT analysis allowed for "situational awareness" of local and global aspects relevant for purposeful and meaningful teacher professional development (Louks-Horsley, Stiles, Mundry, Love & Hewson, 2010) and to compare contradictions across different multilingual science classrooms. But how can such situational awareness initiate expansive learning and inform particular teacher learning and professional development needs? Engeström and Sannino (2010, p. 2) defined expansive learning as collective learning that involves "constructing and implementing a radically new, wider and more complex object and concept for their activity." Contradictions in themselves may not initiate expansive learning, but they can illuminate the teaching areas or problems that PD activities would address to meet the needs of linguistically diverse learners and their teachers.

In the urban private school, concerns around students' language proficiency level were present and "felt" by the teacher, yet these were slighted by authoritarian discourses in the form of strict rules around language use and a societal narrative around the pragmatic and multilingual identity of the Lebanese people (Orr & Annous, 2018; Salloum & BouJaoude, 2019b). The activity systems outlined explicit concerns and contradictions on the effect of students' language proficiency level on science performance; the CHAT-inspired analyses on how teachers' and students' practices are affected by the authoritarian discourses that surround them can facilitate expansive learning: teachers would reflect on such concerns and engage in collective inquiry and practical problem solving towards new instruments and objects for better outcomes (Goodnough, 2018). Initiation of expansive learning requires transformation in the way the object is understood by the community. Thereon, teachers would re-imagine new objects and better understand the need for new instruments that can resolve contradictions and lead to deeper conceptual science learning. Teacher learning would involve more effective instruments to promote diverse participation modes of linguistically diverse students (e.g., pair, small group, and whole group and flexible language deployment), and interactive and multimodal content delivery and students' inquiry (e.g. Lee et al., 2019; Zhang, 2016).

Initiating expansive learning in the public schools is more complex due to different accountability dynamics and the different national and region-level bodies in the community that are outside the school. There are opportunities, however, for expansive learning with self-selected public school principals, teachers, and teacher educators who are interested in starting transformations on different scopes such as class, school, or area (Akkary-Karami & Rizk, 2012). Recently, and partially due to the influx of an increasing number of refugees into Lebanon from neighboring Arab counties (mostly from war-stricken Syrian areas), there is enhanced awareness and interest from official and national professional development entities of the importance of attending to the language demands in teaching science and mathematics. Due to the stark language needs of the Syrian student population, contradictions arose and highlighted the shortcomings of the Lebanese educational system and curricula in addressing such needs (Shuyab, 2016). Accordingly, the needs of many disadvantaged Lebanese students were also placed on the radar. It is hoped that the increasing awareness of such contradictions will initiate expansive learning cycles even if only in certain public schools, as we believe that these schools can become vehicles for wider change.

References

Aguiar, O. & Mortimer, E. (2013, September). Promoting productive dialogic teaching in the classrooms: A challenge to science education. Paper presented at annual meeting of the European Science Education Research Association (ESERA), Nicosia, Cyprus.

Aguiar, O. G., Mortimer, E. F. & Scott, P. H. (2010). Learning from and responding to students' questions: The authoritative and dialogic tension. *Journal of Research in Science Teaching, 47*(2), 174–193.
Akkary-Karami, R. & Rizk, N. (2012). The TAMAM project: Shifting the paradigm of educational reform in the Arab world. *Journal of International Education and Leadership, 2*(3), 1–29.
Anderson, L. & Krathwohl, D. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York, NY: Addison Wesley Longman, Inc..
Bakhtin, M. M. (1981). Discourse in the novel. In M. M. Bakhtin (Ed.), *The dialogic imagination: Four essays by M. M. Bakhtin* (pp. 259–422). Austin, TX: University of Texas Press.
Bakhtin, M. M. (1986). *Speech genres and other late essays (Y. McGee, Trans.)*. Austin, TX: University of Texas Press.
Bourdieu, P. & Passeron, J. C. (1977). *Reproduction in education, society and culture* (Richard Nice, Trans). London, England: Sage Publication Ltd.
Center for Educational Research and Development (2017). Statistical bulletin: Academic Year 2017–2018. Retrieved from https://www.crdp.org/files/201807260129101.pdf.
Center for Educational Research and Development (2020). Studies and researches. Retrieved from http://www.crdp.org/studies?la=en.
Creese, A. & Blackledge, A. (2015). Translanguaging and identity in educational settings. *Annual Review of Applied Linguistics, 35*, 20–35.
Creswell, J. W. & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage.
Engeström, R. (1995). Voice as communicative action. *Mind, Culture, and Activity, 2*(3), 192–214.
Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen & R.-L. Punamaki (Eds.), *Perspectives on activity theory* (pp. 19–38). Cambridge, England: Cambridge University Press.
Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work, 14*(1), 133–156.
Engeström, Y. & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review, 5*, 1–24.
Erickson, F. (2004). *Talk and social theory*. Cambridge, England: Polity Press.
Ford, M. J. & Wargo, B. M. (2011). Dialogic framing of scientific content for conceptual and epistemic understanding. *Science Education, 96*, 369–391.
García, O. (2009). *Bilingual education in the 21st century*. Oxford, England: Wiley-Blackwell.
García, O. & Lin, A. M. Y. (2016). Translanguaging in bilingual education. In O. García & A. M. Y. Lin (Eds.), *Bilingual and Multilingual Education* (Encyclopedia of Language and Education, Vol. 5). Dordrecht, The Netherlands: Springer, Available from: https://www.researchgate.net/publication/306924988_Translanguaging_in_Bilingual_Education.
Garza, T., Huerta, M., Spies, T., Lara-Alecio, R., Irby, B. J. & Tong, F. (2018). Science classroom interactions and academic language use with English learners. *International Journal of Science and Mathematics Education, 16*(8), 1499–1519.
Gibbons, P. (2003). Mediating language learning: Teacher interactions with ESL students in a content-based classroom. *TESOL Quarterly, 37*, 247–273.
Goodnough, K. (2018). Addressing contradictions in teachers' practice through professional learning: An activity theory perspective. *International Journal of Science Education, 40*(17), 2181–2204. https://doi.org/10.1080/09500693.2018.1525507.
Jakobson, J. & Axelsson, J. (2017). Building a web in science instruction: Using multiple resources in a Swedish multilingual middle school class. *Language and Education, 31*, 479–494. https://doi.org/10.1080/09500782.2017.1344701.
Karlsson, A., Larsson, P. N. & Jakobsson, A. (2020). The continuity of learning in a translanguaging science classroom. *Cultural Studies of Science Education*, 1–25. https://doi.org/10.1007/s11422-019-09933-y.
Kennedy, M. M. (2010). Attribution error and the quest for teacher quality. *Educational Researcher, 39*, 591–559.
Lan, S.-W. & de Oliveira, L. (2019). English language learners' participation in the discourse of a multilingual science classroom. *International Journal of Science Education, 41*(9), 1246–1270. https://doi.org/10.1080/09500693.2019.1607618.
Larsson, P. & Jakobsson, J. (2020). Meaning-making in science from the perspective of students hybrid language use. *International Journal of Science and Mathematics Education*, 18(5), 811–830. https://doi.org/10.1007/s10763-019-09994-z.
Lee, O. & Buxton, C. A. (2011). Engaging culturally and linguistically diverse students in learning science. *Theory Into Practice, 50*, 277–284.

Lee, O. & Buxton, C. A. (2013). Integrating science learning and English language development for English language learners. *Theory Into Practice, 52*, 36–42.

Lee, O., Llosa, L., Grapin, S., Haas, A. & Goggins, M. (2019). Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education, 103*(2), 317–337. https://doi.org/10.1002/sce.21498.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38*, 296–316.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Englewood Cliffs, NJ: Prentice-Hall.

Lin, A. & Yi Lo, Y. (2017). Trans/languaging and the triadic dialogue in content and language integrated learning (CLIL) classrooms. *Language and Education, 31*(1), 26–45. https://doi.org/10.1080/09500782.2016.1230125.

Louks-Horsley, S. E., Stiles, K., Mundry, S., Love, N. & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics*, *Expanded* (3rd ed.). Thousand Oaks, CA: Corwin.

Martínez-Álvarez, P. (2019). What counts as science? Expansive learning actions for teaching and learning science with bilingual children. *Cultural Studies of Science Education, 14*(4), 799–837. https://doi.org/10.1007/s11422-019-09909-y.

McCarty, T. L., Collins, J. & Hopson, R. K. (2011). Dell Hymes and the new language policy studies: Update from an underdeveloped country. *Anthropology & Education Quarterly, 42*(4), 335–363.

Moore, E., Evnitskaya, N. & Ramos-de Robles, S. L. (2018). Teaching and learning science in linguistically diverse classrooms. *Cultural Studies of Science Education, 13*, 341–335.

Mortimer, E. F. & Scott, P. H. (2003). *Meaning making in secondary science classrooms*. Buckingham, England: Open University Press.

Orr, M. & Annous, S. (2018). There is no alternative! Student perceptions of learning in a second language in Lebanon. *Journal of Language Education, 4*, 79–91.

Patchen, T. & Smithenry, D. W. (2014). Diversifying instruction and shifting authority: A cultural historical activity theory (CHAT) analysis of classroom participant structures. *Journal of Research in Science Teaching, 51*, 606–634.

Postholm, M. B. (2014). Methodologies in cultural–historical activity theory: The example of school-based development. *Educational Research, 57*(1), 43–58. https://doi.org/10.1080/00131881.2014.983723.

Prinsloo, C. H. & Harvey, J. C. (2018). The differing effect of language factors on science and mathematics achievement using TIMSS 2015 data: South Africa. *Research in Science Education*. https://doi.org/10.1007/s11165-018-9769-9.

Probyn, M. (2015). Pedagogical translanguaging: Bridging discourses in South African science classrooms. *Language and Education, 29*(3), 218–234.

Roth, W.-M., Lee, Y.-J. & Hsu, P.-L. (2009). A tool for changing the world: Possibilities of cultural-historical activity theory to reinvigorate science education. *Studies in Science Education, 45*, 131–167. https://doi.org/10.1080/03057260903142269.

Ryoo, K. & Bedell, K. (2019). Supporting linguistically diverse students' science learning with dynamic visualizations through discourse-rich practices. *Journal of Research in Science Teaching, 56*, 270–301.

Saka, Y., Southerland, S. A. & Brooks, J. (2009). Becoming a member of a school community while working toward science education reform: Teacher induction through a cultural historical activity theory (CHAT) perspective. *Science Education, 93*(6), 996–1025.

Salloum, S. & Abd-El-Khalick, F. (2010). A study of practical-moral knowledge in science teaching: Case studies in physical science classrooms. *Journal of Research in Science Teaching, 47*(8), 929–951.

Salloum, S. & BouJaoude, S. (2019a). The use of triadic dialogue in the science classroom: A teacher negotiating conceptual learning with teaching to the test. *Research in Science Education, 49*(3), 829–857.

Salloum, S. & BouJaoude, S. (2019b). Language in teaching and learning science in diverse Lebanese multilingual classrooms: Interactions and perspectives. *International Journal of Science Education*, 1–33.

Scott, P., Mortimer, E. & Aguiar, O. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90*, 605–631.

Seah, H. & Silver, E. (2018). Attending to science language demands in multilingual classrooms: A case study. *International Journal of Science Education.*. https://doi.org/10.1080/09500693.2018.1504177.

Shehab, S. S. & BouJaoude, S. (2017). Analysis of the Chemical Representations in Secondary Lebanese Chemistry Textbooks. *International Journal of Science and Mathematics Education, 15*(5), 797–816.

Shuyab, M. (2016). Education for social cohesion attempts in Lebanon: Reflections on the 1994 and 2010 education reforms. *Education as Change, 20*, 225–242.

Stake, R. E. (2013). *Multiple case study analysis*. New York, NY: Guilford.

Stroupe, D., Caballero, M. D. & White, P. (2018). Fostering students' epistemic agency through the co-configuration of moth research. *Science Education, 102*, 1176–1200.
Sutton, C. (1996). Beliefs about science and beliefs about language. *International Journal of Science Education, 18*, 1–18.
Vieira, R. D. & Kelly, G. J. (2014). Multi-level discourse analysis in a physics teaching methods course from the psychological perspective of activity theory. *International Journal of Science Education, 36*(16), 2694–2718.
Younes, R., Salloum, S. &, Antoun, M. (2019, May). *The effects of language and parents' education on performance in mathematics and science*. Paper presented at the International Conference on Teaching Science and Mathematics in Culturally and Linguistically Diverse Settings, Nicosia, Cyprus.
Zhang, Y. (2016). Multimodal teacher input and science learning in a middle school sheltered classroom. *Journal of Research in Science Teaching, 53*(1), 7–30.

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