Chapter

Using Language as a Social Semiotic Tool in Virtual Science Instruction

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Abstract

This chapter offers a pedagogical approach for teachers in virtual science teaching that creates virtual hands-on practice for culturally and linguistically diverse (CLD) students to 'do science' and 'talk science'. This chapter features the use of technology applications where elementary- and middle-school teachers create opportunities for students to interact with online simulations, make observations in science experiments, generate claims, gather evidence and reason about concepts to construct oral/written scientific explanations. Scientific explanations are a common discourse practice that scientific communities engage in by interacting with science phenomena during inquiry investigations and present their contributions to science knowledge. The chapter focuses on the practice of constructing explanations utilizing one remote instructional lesson design that would engage teachers of CLD students in online instructional planning. The sociocultural theoretical constructs of mediation and zone of proximal development (ZPD) inform the instructional methods used to create opportunities for CLD students to make sense of science phenomena. Sociolinguistic theory informs the use of language as a social semiotic tool to communicate sense-making. Sociolinguistic theory also guides explicit focus on the structural features of science language that inform language scaffolding and meaningful activity planning intended to promote content-specific language output (e.g. science explanations) by CLD students.

Keywords: systemic functional linguistics, explanations, sociocultural theory, remote science teaching

1. Introduction

In early 2020 the Coronavirus worldwide pandemic set into motion a sudden mass movement from traditional face to face instruction to remote teaching. The sudden transformation in instructional delivery presented many challenges to education agencies, administrators, teachers, students, and families. Several challenges were encountered, including access to technology devices, access to internet service, and access to and proficiency in the use of virtual platforms for teaching and learning. This chapter presents one pedagogical approach informed by sociocultural and sociolinguistic theoretical frameworks, where one teacher educator offers how to use language as a social semiotic tool in virtual science instruction to engage culturally and linguistically diverse students in science learning. This teacher educator integrates content, language, and technology as one way to actively engage CLD students in learning through science-specific disciplinary language for experiencing scientific phenomena to make sense of it through language. Teachers are invited to apply the pedagogical approach offered to engage students in remote science learning through the use of common scientific discourse practices, such as constructing science explanations. The theoretical framework informing the approach explains the constructs and significance of mediation, zone of proximal development (ZPD), interaction, and Systemic Functional Linguistics (SFL) to put into practice in lesson delivery for virtual implementation.

2. Theoretical framework

In this chapter, the author integrates sociocultural and sociolinguistic theoretical frameworks to propose a pedagogical approach in virtual science instruction. The integration of the two frameworks proposes a pedagogical approach on how to utilize language as a social semiotic tool for sense making in science remote instruction. Systemic Functional Linguistics (SFL) offers one genre for sense-making in science, the explanation genre. The theoretical framing is described next.

2.1 Sociocultural theory

In [1], sociocultural theory is concerned with how individual mental functioning is related to historical, cultural, and institutional context. "Hence, the focus of the sociocultural perspective is on the roles that participation in social interactions and culturally organized activities play in influencing psychological development" ([1], p. 1). According to sociocultural theory [1], learners participate in activities and internalize the effects of working together and in the process acquire knowledge and strategies of the world and culture. Wertsch and Lantolf [2, 3]. identified that the human mind is mediated through the use of culturally constructed tools and signs, which are also known as semiotics. Semiotics include physical tools and symbolic artifacts. According to [4], physical tools help humans mediate experience of their physical world through concrete tools (e.g., computers, objects, layout of built environments), whereas symbolic tools (e.g., language, literacy, concepts, numeracy) help mediate the individual's connection to the social world. Through the use of both types of tools, humans mediate their individual experience to their social and material world for sense-making. Thus, in science teaching it is important to identify the physical tools (diagrams, maps, models, etc.) and symbolic tools (language, literacy, concepts, etc.) to help students make sense of their learning as they interact with scientific phenomena in similar ways that scientific communities do.

Further, Vygotsky [5] defines the *Zone of Proximal Development* as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined by independent problem solving under adult guidance or in collaboration with more capable peers" ([5], p. 86). This collaboration from more experienced adults (as in the teacher) and more experienced peers (novice and expert peers) is critical for scaffolding learning tasks to get students from their actual learning potential to the next potential level. Because sociocultural theory promotes development over time through the use of physical and symbolic tools, the ZPD is a central construct for developing understanding over time through the process of internalization, where learners rely less on external tools and gain the capacity to perform more complex tasks due their reliance on internal mediation [4]. This is why the provision of external tools in the form of scaffolding are meant to be provided for moving students from actual development levels (where there is more reliance on internal mediation) to potential developmental levels until internalized by the learner to move to the next potential development level. All of this happens through the recurrent external and internal use of scaffolded conceptual and linguistic tools and why it is important to afford students with multiple ways to experience and talk science.

Since the language of scientific communities requires specific uses of it in the discipline, it is also important to highlight constructs within sociolinguistic theory for utilizing language resources for sense-making.

2.2 Sociolinguistics theory

Hudson ([6], p. 4) defines sociolinguistics as "the study of language in relation to society, implying (intentionally) that sociolinguistics is part of the study of language." In this chapter it is important to note the intentional use of language as a symbolic tool for sense making and interacting in science. In doing so, the author will highlight common structural language forms or genres frequently used by the scientific community to make sense of their scientific worlds. The author accentuates the specific genre of science explanations as a social semiotic tool for sense making. First, social semiotics is concerned with meaning making and how language users make sense or meaning through language. SFL [7], proposes that language resources are shaped by how they are used by people to make meaning in the social function of language through three metafunctions: (1) ideational, (2) interpersonal, and (3) textual. The ideational metafunction is concerned with what is going on in the world to reflect experiential meaning about the world. The interpersonal metafunction relates to the use of language resources to interact with others. Lastly, the textual metafunction of language offers grammatical resources that work together to help language users create coherent and cohesive texts (written or oral). The textual metafunction links the ideational and interpersonal metafunctions to create a unified text [8].

Since this chapter offers a pedagogical approach for science teachers to use language as a social semiotic tool in science teaching, the author offers a few traditional common texts used for science sense making. One of the most frequently used texts are lab procedures, which traditionally include step by step instructions for carrying out a lab investigation. Another text may be a report, which would serve to communicate the findings of a lab investigation. These are more traditional in nature and more typical of taking place during face-to-face instruction and lab investigating activities. However, when scientists communicate inquiry investigations, they often do so using explanation and argumentative texts which serve the purpose to explain processes and cause-effect relationships intended to persuade their audience, which includes other members of the scientific community. Regardless of the text type at hand, one feature of frequently used science texts is that they include highly abstract and technical language. It is important for science learners to experience and interact with scientific phenomena to make sense of it before being expected to communicate through highly specialized science language. In this chapter the author offers one pedagogical approach using one specific science genre (text) to scaffold the content and language tasks for CLD students. The approach offers teachers lesson design components to consider when planning the content and language tasks that will assist students to construct science explanations. Since the Coronavirus pandemic has transformed the way of instruction in face to face and remote instruction, I offer this approach as one to be planned for remote instruction, but that could also benefit those teachers using hybrid modes of instruction as many are returning to face to face instruction.

3. Pedagogical approach

The pedagogical approach offered here is one intended to integrate content and language learning for mediating science learning to 'do science' and 'talk science.' As mentioned previously, one text type (genre) will be highlighted in this chapter as a language resource to mediate experience in science learning through the use of physical tools (online simulations) and symbolic tools (language). First, this author proposes the structural layout of the social semiotic tool of explanation texts in science. They can be sequential in nature to explain how a process occurs or they can be causal in that they explain cause-effect relationships. Thus, one item to consider in lesson design (online or face to face) is the language tasks students will engage in when constructing science explanations to interact with their peers and teacher. In sequential explanations, Humphrey et al. [8] describe these as the phases of a process in sequence to reveal how a process occurs (e.g., the process explained in the water cycle through each phase), whereas causal explanations may explain sequence but also why the process occurs (e.g., heat's effect in each phase of the water cycle).

3.1 Instructional process

One instructional process commonly used in teaching is the 5E cycle. The 5E cycle includes the following instructional processes a teacher plans to provide experiential learning opportunities to students: (1) engage-teachers work to gain an understanding of students' prior knowledge; (2) explore-students actively explore new concepts through hands-on activities (or virtual hands-on learning experiences); (3) explain-helping students organize new knowledge and ask clarifying questions for what they learned during the explore phase; (4) elaborate-students apply what new knowledge they have learned; and (5) evaluate-teachers plan for assessment or observation to determine if the core concepts of the lesson have been clearly understood by students. This author wants to focus on the explore and explain phases of this learning model for instructional planning that provides students with opportunities to 'do science' and 'talk science'.

While language as a social semiotic tool is important for sense making and activities reflecting how students do this through the construction of science explanations, equally important is the experiential component of interacting with science phenomena. In face-to-face teaching this happens mostly during lab investigations, where students are afforded hands-on experience with lab equipment, substances, and manipulation of variables in lab investigations to observe and measure the effect of these. In remote teaching, the physical hands-on experience is not possible. However, virtual hands-on tools can be used in place of physical tools for students to engage in learning during the explore phase. One example of such a tool can be virtual simulations. The sudden mass movement required many education stakeholders to explore the availability of virtual resources for remote teaching. Some examples include learning management systems (BlackBoard, Canvas, Moodle), while there are also synchronous teaching technology applications (Zoom, Microsoft Teams, nearpod, Padlet), in addition to game-based learning applications such as Kahoot and online simulations (PhET, Gizmo, CloudLabs STEM) to name a few.

3.2 Planning for student-centered learning

When planning for student-centered learning this pedagogical approach focuses on three aspects to learning so that students (including students from culturally and linguistically diverse backgrounds) are afforded multiple ways to interact with the content learned. One way is frequent experience opportunities with the content. Questions to consider are: (1) How will students interact with the content (visually, orally, videos, simulations)?; (2) What is the language of instruction and what language supports are afforded to CLD students who are not native speakers of a majority language? and (3) What are the intended conceptual and linguistic outcomes that are expected? A response to question three can be addressed by the specific formulation of content and language objectives to determine supports required to answer questions one and two. Technology is then utilized as a tool for exposing students to content and the use of virtual platforms for actively engaging students in the content to produce content and language outcomes. One of the greatest challenges as all educators moved to remote instruction in early 2020 was engaging students. One affordance in learning how to navigate this challenge is the growth in technology literacy and professional development for effective remote instruction that engages students. Thus, a central component when planning a lesson is to consider the specific content and language objectives that can be observed and measured during instruction and what technology platforms and applications will support students' interaction with the content and language to participate in disciplinary language use about the content via multiple modes of communication. Since explanations is the genre (text) of choice in this pedagogical approach. The author will describe the structural and grammatical features of science explanations for teacher planning.

3.3 Science explanations

As previously mentioned, one way to distinguish between the structural features of two common forms of explanations is by considering whether they describe a process or whether they describe a cause-effect relationship about science phenomena. Process or sequential explanations serve as intentional linguistic scaffolding for causal explanations. Thus, in science instructional design one might consider, what processes students will be learning in a lesson. One common type of process can be cycles, as in the water, or carbon dioxide cycle. Another type of process can be chemical processes (e.g., condensation, precipitation, evaporation, chemical changes, etc.) Let us take one content and learning objective as an example of the approach offered in this chapter.

> Content objective: students will identify chemical changes in a chemical reaction.
> Language objective: students will explain why the chemical changes occurred.

For the content objective, identification of chemical changes involves identifying chemical processes (e.g., rotting, burning, rusting, etc.). Taking the example of the burning of sugar, one can observe that there are specific observations that can be made when burning sugar (color change, temperature change, phase change, etc.). A sequential explanation may include the observations made when heat was applied to sugar. One example of a sequential explanation may be the following:

Sequential explanation:

Heat was applied to a container that contained sugar (test tube).
The sugar appeared white and in solid (granulated) form.
The sugar started smoking.
It is easy to observe that the smoking is indicating a change in temperature.
The sugar started turning brown or burning.
The white solid became a brown and thick liquid.

The underlined portion of the above explanation is one way to measure the outcomes intended by the content objective (i.e., burning). The language objective now requires a causal explanation, which can be a sequential explanation plus a causal component. Notice that the sequential explanation offers a sequence of events of how the burning of sugar occurred. A causal component would require answering why the chemical process of burning occurred. In this case the increase in heat (cause) resulted in the formation of caramelized sugar (effect). One commonly used causal explanation framework utilized in science teaching and learning is the *Claims, Evidence, Reasoning* (CER) framework proposed in [9]. The CER framework supports instructional planning for teaching through the use of science explanations by scaffolding the explore and explain phases in the instructional process to provide students with opportunities to generate claims (which can be an answer to a question, or a conclusion drawn), opportunities to make or measure observations as evidence in support of their claim, and opportunities to justify why the evidence supports their claim through the application of scientific principles. In the above example, one applicable scientific principle can be that whenever there is a chemical change a chemical reaction results in the formation of a new substance with a different structure and different chemical/physical properties (i.e., started with granulated sugar or sucrose, the chemical change of burning resulted in the transformation of sucrose into caramel).

3.4 Interaction

Interaction being a critical component of both sociocultural theory and sociolinguistics for individuals to mediate human experience of the world requires providing opportunities where students can become active participants of science discourse. Since, explanations are one genre (text) commonly used in scientific communities, providing students opportunities to construct science explanations about science phenomena affords them ways to begin learning to use language in similar ways to scientific communities. The construction of science explanations in the example above is a prime example of how science texts, as in the use of the CER explanation framework, require a carefully constructed text that is coherently and cohesively organized to communicate meaning. This is symbolic of the textual metafunction of SFL. Equally important though is the interpersonal metafunction of SFL for using language as a social semiotic tool for sense-making. Science learners, as text composers, must consider who their intended audience is and what the subject matter is to communicate meaning via science explanations. Under these circumstances, students communicate with other students and with the teacher about science-specific concepts and phenomena. Thus, teachers are encouraged to be very intentional in their planning of interaction opportunities to promote student-student interaction in addition to student-teacher interaction. It is important that the interaction opportunities be aligned to both the content and language objectives of the lesson. Interaction opportunities were one of the most experienced pedagogical challenges when the sudden movement to remote instruction was made. Platforms like Zoom permitted the use of breakout rooms, as one way to promote student-student interaction. However, it became quite difficult for the teacher to go from one breakout room to another, and while students were in breakout rooms, teachers were not able to view what interaction might have been occurring in other breakout rooms where the teacher was not present. Because of this, this author proposes the integration of technology platforms and applications that permit the technology resources to promote student-student, student-teacher, and teacher-student interaction in more concurrently visible ways. Some applications that capture the live interaction in whole virtual group (versus small break out groups) are described next.

Padlet is an interactive platform that gives the teacher access to all student communications. The comment posting feature captures language outcomes in written form. In doing so, students are able to post their science explanations. The platform permits the use of videos and links to online simulations for students to interact with content. Padlet also allows the ability to post voice memos. When working with students of CLD backgrounds, such as second language learners (SLL), posting comments onto a Padlet gives SLLs opportunities to develop their writing skills, whereas voice memos, affords them oral language opportunities and practice with listening comprehension. Further, this application provides students with opportunities to mediate science learning using language as a social semiotic tool to make sense of their learning experienced. Other applications such as nearpod have similar features, while online simulations offered by PhET offer great virtual hands-on experience for students to interact with the content via online simulations.

3.5 Scaffolding

Returning to the content and language objectives component for planning a virtual hands-on lesson, one must also consider the exploration phase of the 5E lesson cycle to intentionally decide what experiences to provide students with to scaffold their learning at the actual development level and assist them to advance to the next potential development level. This must happen at both the conceptual and linguistic levels. Recalling that the use of physical tools provides external mediation opportunities for students, language (specifically the language function of explaining) is one that can be internalized in some form of actual development for SLLs but should always be scaffolding the language tasks at potential developmental levels for second language learning. This approach promotes both content and language development through intentional planning.

In the use of sequential and causal explanations aforementioned, it is important that conceptually, students understand a process first before expected to understand causal conditions of manipulating a process for a specific outcome (effect) to occur. This level of scaffolded instruction targets both conceptual understanding and linguistic communication to experience science and communicate about science phenomena experienced. Further, for CLD students who are learners of a second language, linguistic scaffolding also develops their language competence and proficiency over time, hence why language practice through interaction opportunities are so critical for this student.

4. Discussion

The integrated sociocultural and sociolinguistic theoretical framework informs a pedagogical approach where constructs like mediation, zone of proximal development, and interaction suggest using language as a social semiotic tool for science sense-making. Through the three metafunctions of language in SFL—ideational, interpersonal, textual—and the genre of science explanations, teachers use this integrated approach to intentionally plan for the targeted learning experiences in the *explore* phase to 'do science' and *explain* phase to 'talk science.' Since the coronavirus pandemic required a sudden mass movement from face-to-face instruction to remote instruction, it was also critical for this teacher educator to offer technology platforms and/or applications that would provide teachers of students with resources for planning the science *explore* phase. Thus, the approach offered here suggests the use of applications including but not limited to Padlet, nearpod, Kahoot, and PhET simulations to provide students with virtual hands-on practice to experience science learning. However, the same applications are also offered to teachers so that they are used for communication purposes using one genre commonly used by scientific communities—science explanations. Using this virtual pedagogical approach provides teachers with very intentional planning for conceptual and linguistic outcomes that together provides students with opportunities to mediate science learning, make sense of scientific phenomena, and engage in interaction through the use of science explanations. Use of the 5E instructional process, while always prioritizing the conceptual and linguistic outcomes of students, assists teachers in determining the scaffolding required in both content and language production to move students from actual to potential knowledge development levels as one way to be intentional about their zones of proximal development.

Implications for research suggest instructional interventions designed to measure second language learner conceptual and linguistic outcomes. Such interventions would inform intentional content and language teaching through measurement of fidelity of implementation. Interventions would measure student-intended content and language outcomes for CLD students. Additionally, instructional interventions would explore the effect of conceptual and linguistic scaffolding and their removal as students move from one knowledge development level to another. Lastly, interventions using this approach would help further inform the use of technology to enhance students' opportunities to explore science learning and communicate via discipline specific language use.

One limitation of this chapter is that the author centers only on one specific genre—explanations. Constructing arguments and the language skill of engaging argumentation not only requires the use of explanations, but also requires the use of persuasive language resources to persuade the scientific community and continue the construction of new scientific knowledge. In a classroom, students should also experience opportunities to engage in argumentation to experience different ways of knowing or epistemologies between them and their peers, but also ways to evaluate their own learning and refine their conceptual understanding of science phenomena.

5. Conclusion

This chapter concludes with the components of a pedagogical approach in virtual science teaching that aims to provide virtual hands-on content and language practice for culturally and linguistically diverse (CLD) students, such as SLLs, to 'do science' and 'talk science'. The author featured the use of technology applications in which teachers create opportunities for SLL students to interact with online simulations and use the CER explanations framework to construct oral/written scientific explanations. Constructing scientific explanations is a discourse practice in scientific communities used to communicate understanding and findings about inquiry investigations and make contributions to science knowledge construction. Sociocultural and sociolinguistic theories informed the pedagogical approach presented to better understand how language is used as social semiotic tool for sense-making. The sociocultural theoretical constructs of mediation and zone of proximal development informed the instructional process used in the explore and explain phases of the 5E learning cycle to create opportunities for CLD students to make sense of science phenomena. Sociolinguistic theory informs the use of language in the ideational, interpersonal, and textual functions through Systemic Functional Linguistics to propose how students can interact with content and explain science phenomena in coherent and cohesive ways.

Conflict of interest

The authors declare no conflict of interest.

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