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FORUM

Heterogeneous performances of conceptual dis/continuity: a dialectic reading of Brown and Kloser's article

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Abstract We review Brown and Kloser's article, "Conceptual continuity and the science of baseball: using informal science literacy to promote students science learning" from a Vygotskian cultural-historical and dialectic perspective. Brown and Kloser interpret interview data with student baseball players and claim that students' conceptual understanding articulated in vernacular genres involves continuities (similarities) with the canonical scientific explanations. In this commentary, we suggest that the authors' approach presupposes the dichotomy of the formal and the informal, which brings the authors' attention to continuity into the separation of cognition from language. We propose a Vygotskian approach that points out the problem of theorizing cognition (conceptual understanding) by depending on specific forms of representation (e.g., scientific terms). As alternative, we envision a Vygotskian cultural-historical approach to language, which considers different, irreducible modes of communication as an integrated whole and therefore allows theorizing cognition without dichotomizing it from the concrete ways by which human being communicates. We provide an exemplary analysis of a lecture talk in a university physics classroom and exemplify dialectic theories that explain the development of conceptual understanding. We discuss that this Vygotskian dialectic approach shows that people communicate scientific concepts through *hybridization*, which does not reproduce a genre self-identically; the continuity of conceptual understanding involves dis/continuity.

Keywords Language · Conception · Hybridization · Genre · Dis/continuity

Language comes central to learning science in many scholarly articles of science education from the fact that knowing science constitutes a way of talking and also that learning this way of talking is mediated by talking, that is, linguistic interaction. Among these related two aspects of language, the former often leads researchers to theorize science as a special kind of culture and language distinguished from others and therefore learning science as

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accommodation to the special scientific language/genre. The latter leads researchers' attention to students' everyday linguistic interaction and therefore underlines the significant role of local languages in understanding science concepts. However, the simultaneous consideration of the two different aspects of language indicate that students' (discontinuous as a result) transfer to a different way of talking has to occur from and through their mundane, locally grounded, everyday talking. This proposes a contradictory dialectic problem (i.e., dialectic of learning science): The language that students are supposed to speak as an outcome of their conceptual understanding (i.e., learning science) should constitute the current means of talking so that conceptual understanding is possible. The different way of talking that students are supposed to learn (i.e., science) constitutes the very necessary conditions for achieving conceptual understanding.

Brown and Kloser in their article on informal science literacy confront this dialectic problem of language and deal with it by drawing on the notion of "conceptual continuity." The two authors empirically take into account student baseball players' verbal explanations of "why a curveball curves" at interview sessions and analyze their conceptual understanding by using the framework of discursive genres (e.g., science vs. alternative). They categorize students' linguistic explanations and report that students' explanations (i.e., conceptual understanding) articulated with words from vernacular genres (e.g., everyday, baseball) show similarities with canonical scientific explanations of the curveball. Therefore, they claim that scientific understanding does not necessarily have to be limited to the mobilization of particular words/genres (i.e., scientific languages) but involves continuity that goes beyond the boundaries between different genres. For example, they articulate that students' utterances like "push" and "pull" and "falling off the table" pertain to the scientific concepts of speed and velocity although those terms are traced back to students' everyday experiences and baseball training (i.e., everyday and baseball genres). In this way, the authors attend to discursive possibilities that students' local ways of talking can develop into with respect to conceptual understanding. Therefore, they doubt the framework and application of learning theories which dichotomize scientific language from other vernacular/naïve/local genres of discourse to examine students' conceptual understanding. The authors claim that a vernacular language is an "asset" that is crucial to conceptual understanding rather than in "deficit" or a source of "problem."

From a Vygotskian cultural-historical perspective, a right way to resolve the dialectic problem of language is to abandon the dichotomy of the legitimate and the illegitimate and acknowledge students' participation as an instance of cultural practice of talking science (e.g., Goulart and Roth 2006). On the one hand, Brown and Kloser's claim on conceptual continuity may look like expanding the linguistic boundary of knowing science and therefore challenge the traditional paradigm of teaching science. Yet, on the other hand, we find that Brown and Kloser's approach involves some limitations, which hinder their movement toward the recognition of the cultural dialectics in learning science.

First, we find that the authors' decomposition of students' interview talks into different discursive genres misses an important point: the interview conversation constitutes a whole meaningful context of talking science (Roth et al. 2008). In the interview situation, the student baseball players participated in talking about a scientific representation. They developed their interpretations to/for the science educator(s) who brought the representation and asked them some questions. Student baseball players may use words/expressions that are found in baseball training communication, but this does not justify that they are speaking in the baseball genre. We understand following a Vygotskian cultural-historical approach that a baseball genre/language is inseparable from the activity of doing baseball, that is, from a concrete human activity in and by which language marks sense (Bakhtin

1986). The situation or the context of talking (interview) constitutes inseparable part of knowing science. However, Brown and Kloser identify genres mainly by depending on words and word expressions, and thereby separate language/genre from real people speaking language. Although the authors' claim actually supports the position that the distinction between formal and informal literacy does not constitute a right framework for understanding "conceptual understanding," the authors keep this separation (formal/informal) and therefore talk about 'continuity' only in reference to the science genre toward which students' informal language needs to be assimilated in whatever ways.

Second, the authors' interpretation of students' conceptual understanding does not seem to be well addressed by empirical justifications. For example, the authors explain that they "were less focused on what words were used and more concerned with how these student-athletes were able to use baseball discourse to describe." However, it is not clear what empirical aspects of language other than words they analyze when they propose claims such as "say[ing] a science term without truly understanding the concept associated with it" or "similarities" of conceptual understanding in the vernacular genres with canonical ideas. The authors do not articulate what linguistic resources they refer to when they analyze the "function" or "use" of words. Moreover, the authors separate two modes of conceptual continuity: cognitive and linguistic, for which we also do not know how the authors could analyze "cognition" other than through linguistic resources that they have gotten from interview talks.

To sum up, the authors' separation between the formal and the informal takes a word-centered and atomistic approach to language. The authors' theorization of 'continuity' within the framework of the formal–informal dichotomy leads the authors to dichotomize cognition from language. The concept of "conceptual continuity" seems to separate cognition (understanding science concepts) from language (communication) and does not address the dynamic dimension of language that makes learning science possible. This way of reading Brown and Kloser's paper leads us to find that a theory of language that does not dichotomizes formal and informal science literacy is required to take into account cognition without mystifying it or simplifying it into some partial aspects of language activity (words). The purpose of this commentary is to articulate a non-dualistic framework of language and literacy and highlight its significance to theorizing conceptual understanding of science. We keep Brown and Kloser's main argument presupposed in their claim of "conceptual continuity" (i.e., the significance of everyday language in learning science and its discursive possibilities with respect to learning science). We follow sociocultural theories of learning that does not dichotomize formal and informal literacy (e.g., Lave 1997). We take a Vygotskian cultural-historical and dialectic perspective and articulate concepts for holistically understanding language without making a dualistic dichotomy with cognition. We show that the concepts of hybridization and crossing the boundaries constitute a theoretical framework. We provide concrete analyses of case examples selected from an undergraduate physics lecture and exemplify our points.

Conceptual understanding: a Vygotskian review

Mijung: To explain students' conceptual understanding, the exhibition of scientific language in students' talks has been recognized and analyzed as the signs of cognitive development. Students demonstrate canonical terms which are already accepted in scientific communities and therefore, have understood scientific concepts. However, it has been proven that there exists the resistance of changing the ways of students' talk into scientific languages since students are embedded in their existing experiences and use everyday

language as sources and resources for building analogies and meanings of scientific cannons. If the claim of students' learning depends entirely on the terrain of language and the development of concepts depends on changes in their science talks, conceptual change or conceptual development is not much expected because of the strong resistance to changing their ways of talking. Even if conceptual understanding might take place in the domain of their existing practice of language, it cannot be explained as a development of conceptual understanding since scientific terms have not been exhibited yet and therefore, no developmental notion can be proven. This linguistic outcome-based approach bears some limitation to explain students' conceptual understanding and learning. It cannot explain the process of conceptual understanding of how students have come to use certain scientific terms and how different terms and language co-exist and interact in learning situations. It only exhibits the evidence of linguistic re/presentation of scientific terms at the certain point of learning period, not being able to understand the interactions of different languages, genres and situations of students.

SungWon: The division of literacy to the formal and the informal is one of the dualistic dichotomies presupposed in Brown and Kloser's approach to their interview data with the student baseball players. Perhaps traditional science education studies on conceptions/conceptual change are deeply grounded in this dichotomy regardless of whether they theorize the informal positively or negatively. Although Brown and Kloser criticize the traditional paradigm that takes a "deficit perspective" to "native discourse," they still depend on this traditional dichotomy and keep the gap between the formal and the informal within their claim on continuity. Their comparison between students' conceptual understanding in the informal contexts and canonical scientific ideas follows this framework.

Mijung: Extracting the informal or the formal from the context of what is being explained would be difficult to approach students' conceptual understandings. To understand scientific concepts and employ scientific terms in their science talks at certain stages of learning, students need to cross the boundaries of their everyday experiences and languages and new ways of scientific explanation. In crossing boundaries of different situations, genres, and languages, new ways of knowing and saying occur which brings out the heterogeneous nature of knowledge; "hybridization." The term, "hybrid" or "hybridized" is different from Brown and Kloser's use of "hybrid" as one of their four genres. I adopt the term from Wolff-Michael Roth (2008) study "Bricolage, métissage, hybridity, heterogeneity, diaspora," which means the heterogeneous nature of knowledge and communication situated in knowers' living/lived worlds. Learning is the process of hybridization between existing and new ways of doing and saying. In the communication of scientific concepts, students' everyday experiences are inherently embedded in their ways of talking and conceptual understanding.

SungWon: From a Vygotskian cultural-historical perspective, a minimum unit required for analyzing people knowing and learning is a societal activity (e.g., doing baseball, schooling, or doing research on learning science) in and for which people communicate and their collaboration marks senses (e.g., Leont'ev 1978). Different activity systems may have their own singular (sub-) cultures and languages, which is addressed by the formal–informal dichotomy or the differentiation of discursive genres. Yet, the very possibility of crossing the boundaries between different (sub-) cultures and languages (e.g., students baseball players participate in baseball training, studying science, and talking in research interview) presupposes the heterogeneous nature of language and context. The presence of different discursive genres that Brown and Kloser claim with their analysis of their interview talk denotes the heterogeneous nature of any genre in people talking (Roth 2008), which disappears as an analyst takes an atomistic approach to the heterogeneous whole.

Mijung: Their approach to conceptual understanding values the different modes of understanding students' knowledge development whereas the ideology of purity leads the idea of one true scientific knowledge against which all to the forms of knowledge are evaluated, asked to be abandoned, and even to be eradicated as misconception. The student baseball players were exposed to extensive out-of-school experiences (baseball training) and bodily knowledge which ground them into the experiential understanding of the curve ball. Later, scientific terms appeared to explain their knowledge and experiences in different forms of language, which, however, was not significantly noticed in their study. Transferring their understandings into new forms of knowledge is difficult since the students could find themselves in a different world, different values, language and forms of knowledge; resistance of changes is rather natural for them. Rather than focusing only on canonical scientific languages, Brown and Kloser questioned how different genres were presented in the students' talks of Magnus forces to look into the development of students' conceptual understanding. Even though the students did not use the specific terms of velocity and speed for Magnus forces or air pressure differential, they could articulate those notions by using everyday and baseball languages.

SungWon: From my view, the author's approach to conceptual understanding could have fitted with Vygotskian dialectic solution to the contradiction, which points out the problem of theorizing cognition by depending on specific forms of representation (e.g., science terms) and proposes integrating different heterogeneous semiotic resources for communication (i.e., communicative performances) at the whole unit of analysis. From a dialectic perspective, transition to a different language presupposes the heterogeneous nature of language and linguistic interaction. Given that Brown and Kloser attempt to analyze not only the words spoken but also the ways by which those descriptive terms constitute the explanations of the phenomenon (the curveball), the authors' notion of continuity might respond to these recent Vygotskian discussions that articulate the heterogeneity of communicative resources for talking science, and thereby the hybridized nature of understanding science concepts.

Mijung: From my perspective, the authors claimed the notion of embodied scientific context in students' talks as "conceptual continuity as cognitive." The authors also explained that the students developed a clear definition of air pressure differential (Magnus forces) in the second year paralleled with non-scientific language (everyday and baseball) in the first year. They claimed it as "conceptual continuity as linguistic." In their distinction between conceptual continuity as cognitive and as linguistic, they pointed out that the students' cognitive conceptual continuity does not necessarily bring out linguistic conceptual continuity (interaction/similarities with scientific language), which means conceptual understanding could take place and be evaluated without changes in scientific language used. This argument reassures that conceptual understanding cannot depend only on the appearance of specific scientific terms in students' talks. The concept of Magnus forces is being represented in the languages of "the air pushes the seams in the top and bottom differently, and the ball drops at the end" or "one side of the ball would be different than the other going through the air." Therefore, the authors claim that conceptual understanding is associated with discursive practice at varying levels of language (e.g., the use of words). Through the notion of conceptual continuity as cognitive and linguistic, the authors attempted to understand the development of students' conceptual understanding. It is noteworthy that they looked into the different genres of students' talk to understand their conceptual development rather than focusing on the appearance of scientific terms accepted in scientific communities.

SungWon: However, I find that the authors' proposal of the (structural) similarities between the vernacular genres and canonical scientific explanations misses out the heterogeneous

nature of a situated activity. It does not articulate the dialectic dynamic of conceptual understanding by which students' linguistic performances develop heterogeneously and therefore hybridize both the vernacular and the scientific genres. This is so because the authors' analysis of literacy does not fully consider the situated context in which communicative performances are continuously made available and make sense among conversation participants; that is, the interview situation in which students baseball players talk about scientific representation (curve ball) in the presence of science educators.

Mijung: It is limited to understand the dynamic of how the students communicated with the science educators during the communication and meaning making process, which is hybridized not only through the linguistic contexts but also situated engagement. In the communicative situation, their talk as the whole activity cannot be reduced into everyday, baseball, or scientific languages. To explain the concept of speed and velocity of curve ball, the student baseball players necessarily brought their everyday experiences with baseball play in the conversation. The baseball and scientific languages are interacting and hybridized as one unique genre, not two languages separately existed in their talk. To understand conceptual continuity or understanding, their talk needs to be examined as one hybrid situation rather than with similarities among boundaries of baseball, everyday, and scientific terms. Once it is dissected, it tends to lose the dialectic nature of discourse which makes discourse a discourse.

SungWon: In the case of the interview situation, the presence of science educators (interviewers) and the presence of a scientific representation constitute the conditions for the variation of language and communication. Brown and Kloser's analysis shows that this hybridization has happened in their interview. The student baseball players draw on linguistic resources available and communicate with science educators on the topic of a curve ball. This is also the case when a science teacher (lecturer) attempts to explain science concepts to their students in their class. They draw on textbook words and representations and other everyday resources.

Mijung: To understand students' talk as a whole activity of conceptual understanding, we also need to bring out the embodied notion of communication. Since the students practiced and understood curve balls through their bodily engagements, the knowledge of curve ball is not only linguistic conceptual but bodily engaged. Their conceptual understanding necessarily embraces dialectic dynamic of linguistic (words) and bodily (gesture) performance. In this regard, it is critical to look into the dynamic of their language and bodily expression in their talk. Given that cognitive process depends on experiences of having a body with perceptual and motor capacities, conceptualization and reasoning is inseparable from bodily engagement (Lakoff and Johnson 1999). The development of knowledge depends on inseparable interactions of mind, body, and social contexts (Varela et al. 1991). This suggests that in order to probe students' conceptual understanding, it is necessary to understand the whole interconnected pattern of activity (linguistic, bodily, and situated engagement) in the students' talk. Yet, in Brown and Kloser's article, the focus of communication was given to linguistic performance (students' words) to understand conceptual continuity with little attention to other mode of representation, that is, bodily engagement and situation of communication.

Literacy and conceptual understanding: toward a holistic approach

In this section, we exemplify a theoretical framework that addresses the heterogeneous nature of literacy and culture and the significance of this framework to theorizing

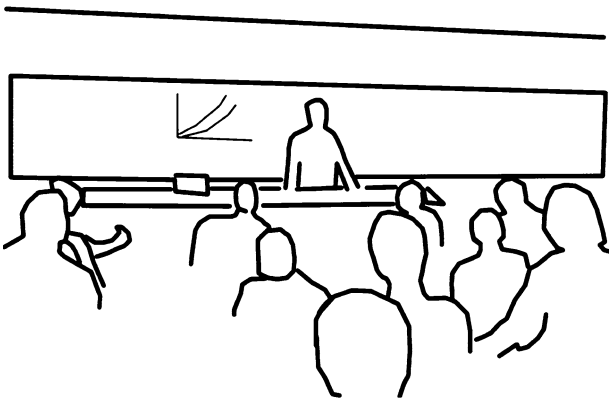

Fig. 1 A physics professor talks about thermodynamics concepts to third-year physics undergraduate students at a university lecture hall

conceptual understanding. We propose that a Vygotskian cultural-historical and dialectic approach to language constitutes an appropriate framework for theorizing conceptual understanding without dichotomizing formal and informal or cognition and language. Following Vygotskian psycholinguistic studies, we integrate heterogeneous communicative performances other than words into the unit of cognition (McNeill 2005). That is, we theorize that communication of scientific concepts or representation is performed in and through the heterogeneous embodied actions. We take a 46-second-long example of a university physics lecture (one of the typical contexts for talking science) in which a physics professor explains a thermodynamics graph and associated concepts to the student audience at a lecture hall (Fig. 1). We analyze an episode and articulate the heterogeneity of lecture talk. We discuss that the central concept for theorizing knowing and learning lies in the hybridization rather than the formal–informal dichotomy.

Transcript 1[1]

01 [EVEN after this]
[((*holds up his right palm* and returns it back to the table*))] (*Fig. 2a)

[1] In this chapter, the following transcription conventions are used (ten Have 1999):
EVEN Capitalization denotes the speech intensity that is louder than normal speech;
[still Beginning of gesture that contemporaneously overlaps the words underlined;
((*bounces*)) Italicized words within double parentheses constitute a transcriber's comments on visible body movements;
* Asterisk mark denotes an instant that corresponds to a drawing (video-offprint) of which the figure number is labeled at the end of the comments;
(1.3) Elapsed time in tenth of a second;
≪p>we're> Lower speech volume (piano) than normal,
(??) Question mark in parentheses indicates inaudible utterance(s);
and: Lengthening of a phoneme is indicated by colon;
?,;. Punctuation marks are used to indicate characteristics of speech production rather than grammatical units;
like- Dash indicates a sudden stop of talk.

02 bounced a million times, there are STILL a millions and

03 [still an INFINITE number of bounces]
[((*bounces his right hand three times on the table**))] (*Fig. 2b)

04 ahead of it (1.3) [≪p>you're done this] in high school
[(((*lifts his palms up*)))]

05 [or you're (??)>] (1.1) it is still infinite bounces ahead
[(((*lifts his palms up slightly*)))]

06 of it, and: but it comes to rest after a finite time, after having covered

07 a finite distance (1.2)

08 and I CAN'T [tell (one bring if?)]
[((*gazes at his notes on the table*))]

09 one of you one of these days, maybe able to think of

10 [some process,]
[((*turns his body to the blackboard and walks to the chalkboard*))]

11 [by which you're]
[((*raises his right hand up and brings the chalk to the right end of the graph*))]

12 [able, to move a]
[((*follows* the stepwise lines of the graph on the board with the chalk*))] (*Fig. 2c)

13 [(0.6) an infinite number, of:, uh:,]
[((*moves his right hand away from the graph and gazes at the right top area of the graph*))]

14 [isothermal]
[((*follows the top vertical line*))]

15 [constraints (0.7) followed by uh]
[((*stops at the lower end of the vertical line and stay still*))]

16 [adiabatic]
[((*follows a top horizontal line from the left to the right*))]

17 [relaxation]
[((*turns* his body from the blackboard to the students*))] (*Fig. 2d)

18 to infinite number of experiments like- like- in a finite amount of time

Description

The physics professor stands behind a table and faces students with a chalkboard (with a graph) on his back (Fig. 1). The students sit toward the front side (the professor and the blackboard) of the lecture room. The professor utters "even after this" (line 01). He simultaneously holds up his right hand and returns it back onto the table; the body movement thereby makes an effect of emphasizing the utterance (line 01). He continues his talk by uttering "bounced a million time, there are still a millions and" (line 02). Thereby he continues his description of a ball that falls and bounces down to the ground. He articulates that even after the ball bounces a number of times, there are still millions of times left to bounce in the next. He utters "still an infinite number of bounces" (line 03) ahead of it (line 04), and thereby articulates that the number of bouncing is infinite. He lightly taps the table three times with his right hand, which constitutes a series of iconic gestures that illustrate a ball in bouncing to the table (line 03). The professor pauses for a second and continues talking in a less loud voice. He articulated that students have done this—the logical infinity of the number of bounce—at high school, and thereby points out that he is talking about something that is already known to students (lines 04–05). There comes another one-second-long pause (line 05). The professor repeatedly articulates "infinite bounces ahead of it" (lines 05–06). He elongates "and" (line 06) and articulates that this infinite number of bounces "comes to rest after a finite time (line 06) and "after having covered a finite distance" (lines 06–07).

The professor utters "and I can't tell" and changes his gaze down to the notes on the table (line 08). He continues uttering "one of you one of these days, maybe able to think of some processes" (lines 09–10). He turns his body orientation from the students to the chalkboard and walks toward it (line 10). He articulates "by which you're able to move a" and simultaneously raises his right hand and the chalk up to the right top of the graph and rapidly follows the stepwise lines of the graph towards the zero point on the left downside (lines 11–12, Fig. 2d). The professor pauses and moves his hand away from the graph (line 13). He gazes at the right top of the graph and utters "an infinite number of" (line 13). He makes an utterance of "uh," which can be interpreted as a hesitation (line 13), and continues saying "isothermal" simultaneously with his right hand following the top vertical line (line 14). His hand stops at the lower point of the vertical line. The professor utters "constraints followed by" (line 15). This utterance is followed by the utterance "adiabatic" and by a hand movement that follows the top horizontal line from the left to the right (line 16). He articulates that this adiabatic process pertains to "relaxation" and turns toward the students (line 17). The professor utters "to infinite number of experiments like in a finite amount of time" (line 18), and thereby articulates a thermodynamic process by which an infinite number of isothermal constraints and adiabatic relaxations happen in a finite amount of time.

Analysis

In this situation, the professor explains a mechanical movement of a bouncing ball. He articulates that a bouncing ball requires an infinite number of bounces until it comes to a rest (lines 01–04). In classical mechanics, a ball dropped from a height and bounced with a lower-than-one coefficient reaches a decreased maximum height (compared to the previous height). If the ball keeps bouncing at a constant rate (i.e., the coefficient is constant), the series of decreasing heights follows an infinite geometrical series. This mathematical logic informs that the ball has to bounce an infinite number of times until it comes to rest. A bounced ball always has a certain amount of distance to reach in the next, although the maximum height gets very small after it bounces a number of times. However, this does

not mean that it takes an infinite time for a bouncing ball to rest on a floor, which Greek people discussed in terms of Zeno's paradoxes (e.g., the arrow paradox). The sum of a geometrical series is finite—i.e., a bouncing ball stops on a floor in a finite time after it covers a finite distance. The professor reminds students of their learning at high school (lines 04–05) and articulates this principle of motion (lines 05–07).

The professor's talk about a bouncing ball in this situation constitutes already a form of hybridization. One may claim that the professor seems to be talking about a topic that does not constitute the genre that he is supposed to speak in this lecture course. The physics of a bouncing ball may not belong to the area of thermodynamics but to another (sub-) area of physics (i.e., classical mechanics) or everyday genre. A bouncing ball is everywhere. People easily find examples of a bouncing ball in their everyday lives. Whereas thermodynamics cycles usually involve a complicated set of machines of cooling, heating, and increasing or decreasing pressure, a ball and its bouncing motion constitute a topic of classical mechanics. However, we find that the professor's communicative performances realize the topic as constitutive part of the ongoing thermodynamic class. First, the professor's utterances associated with other embodied communicative productions (e.g., gesture, prosodies of speech, and body position) constitute a specific (hybridized) genre of talking that addresses what students need to understand and learn to speak as part of their participation in this lecture talk. For example, the pitch of his speech gets higher when he speaks words "even" (line 01), "still" (line 02), and "infinite" (line 03), which thereby highlights that there are a number of upcoming bounces and it is actually infinite. The professor's articulation theorizes the motion of a bouncing ball using a particular framework (i.e., infinite bounces, finite time, and finite distance). The professor interprets the physical motion of a bouncing ball and produces interpretive means that are publicly made available. They constitute hybridized linguistic resources that anyone in the lecture hall may use to continue talking in the next. Second, the presence of the audience (i.e., undergraduate students) and the professor's orientation toward them conditions the constitution of this hybridized form of lecture talk. The professor's embodied performances exemplify it. For example, the professor stands toward the students and uses a podium as part of his speech (e.g., bouncing on the table). More so, the professor's mentioning about "high school" and his use of an assumption (i.e., high school topic) (lines 04–05) explicitly shows that his talk is oriented toward a specific group of audience. Therefore, the professor addresses some aspects of the everyday description of a bouncing ball in this thermodynamics lecture in such a way by which they mark sense with respect to the ongoing study of the thermodynamic cycle (i.e., the graph on the board, Fig. 2).

In the next (lines 08–18) the professor's talk about a bouncing ball is connected to the graph of a thermodynamic cycle on the board (Fig. 2). The professor gazes at his notes on the table (line 08) and turns his body toward the graph on the blackboard (line 10). The professor verbally articulates the possibility of a thermodynamic process that makes an infinite number of isothermal-adiabatic cycle within a finite amount of time (lines 12–18). Simultaneously, the professor's hand movements (e.g., following the lines [lines 12–16]), make a downward stepwise motion and thereby realize a physically and metaphorically similar pattern of motion with that of a bouncing ball. The professor does not explicitly articulate that he takes an example of a bouncing ball as an analogy for thinking about the isothermal-adiabatic thermodynamic cycle. Yet, his hand movements and finally his utterances of "infinite number of experiments" (line 18) and "a finite amount of time" (line 18) draw on some of the communicative resources produced in the course of talking about a bouncing ball. Those embodied actions not only articulate the thermodynamic cycle in a structurally similar way with the motion of a bouncing ball but also explicitly let the latter work as an analogy for the former.

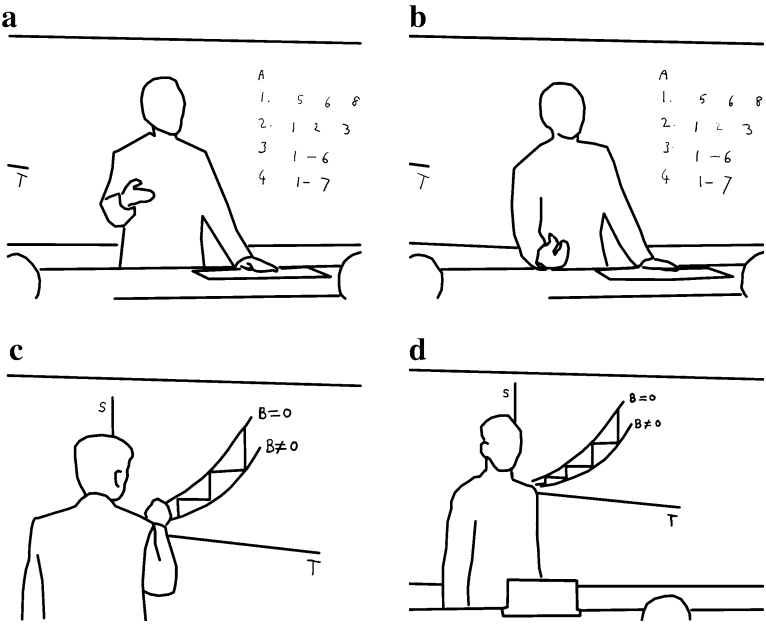

Fig. 2 **a** The professor holds up his right palm. **b** The professor bounces his right hand on the table. **c** The professor follows with a piece of chalk the stepwise *lines* between the *two curves*. **d** The professor turns from the blackboard and faces the students

The professor's embodied actions constitute a unit that cannot be reduced to a simple combination of two different topics (i.e., a bouncing ball and a thermodynamic cycle that consist of isothermal constraint and adiabatic relaxation). The professor talks about the possibility of making an infinite number of isothermal constraint and adiabatic relaxation within a finite time. Not only the use of the same words (i.e., "infinite number" [lines 13 and 18], "finite amount of time" [line 18]) but also the hand movement timely coordinated with those words (e.g., turning toward the graph [line 10], following the stepwise lines between the curves [line 12, lines 14–16], gazing at the graph [line 13]) constitute linguistic resources for taking the case of a bouncing ball motion as an analogy for understanding the physical properties of the thermodynamic cycle. The different embodied actions and their role of hybridization with respect to both the vernacular and the canonical science constitute the central aspect of communicating concepts. The professor's performances are interpreted to be knowledgeable because he produces a hybridized form of talking, and thereby presents the concept through his 'heterogeneous' performances.

Comments

In response to Brown and Kloser's differentiation of genres and their claim on continuity across them we review an example of a physics lecture from a Vygotskian perspective. We thereby present a different way of understanding conceptions in talking science. Brown and Kloser claim "conceptual continuity" by focusing on the structural similarities that the students' use of the words makes with respect to scientific ideas (e.g., the concepts of speed and velocity). In the above analysis of the episode, we show that embodied communicative

actions and their interrelated relation constitute the central aspect of the professor's lecture talk that realizes the continuity between the motion of bouncing ball and the thermodynamic cycle. The professor's talk introduces students to the concept of the third thermodynamics law by providing different (heterogeneous) embodied communicative resources and also resources for interrelating them. In this lecture, getting a better understanding of the thermodynamic cycle (the graph on the chalkboard) requires a better understanding of the motion of a bouncing ball. The two develop together as one hybridized unit. In this framework, we don't separate conceptual understanding into cognitive and linguistic event. Rather, we analyze ongoing (participative) thinking by analyzing a whole unit of communication that are publicly made available through embodied actions and the interrelation between them. In real people's talking, science concepts are articulated through the hybridization with vernacular genres. Therefore, we comments that the structural similarities that Brown and Kloser focus on would be rightly understood within the whole framework of communication, which encompasses not only words but also embodied actions that are deployed between interviewer-interviewee one another and also with respect to scientific representations and other structural resources.

Coda

In this commentary, we review Brown and Kloser's article from a Vygotskian perspective, which does not dichotomize either knowing from the context or words from other embodied communicative resources. We show that the continuity of conceptual understanding centrally presupposes the heterogeneous nature of communication and the hybridized nature of science genre. That is, the hybridization (discontinuity) is central to the continuity of conceptual understanding. Yet, the aspect of discontinuity is different from the formal division of genres or the gap between the formal and the informal. A Vygotskian theory of conceptual understanding helps understand learning not solely by theorizing intentional aspects but by acknowledging the passivity involved in the act of participation (e.g., Roth et al. 2008). The physics professor's talk is a product of his participation in university physic teaching in general and his communication toward the specific group of audience in particular. Likewise, the student baseball players' translation of the representation ("why does a curveball curve") can be seen as a product of communication in which different communicative actions are mobilized and simultaneously hybridized. In either case, a communicative action does not fully belong to individuals. The human material body in communication is central to this production of the heterogeneous communicative resources and the hybridization of the vernacular in the development of conceptual understanding. Thus, the professor's body plays a key role in articulating a bouncing ball example and making a transition toward a topic of thermodynamic cycle. The role of the body in communication constitutes a key aspect for understanding the significance of everyday language to the development of conceptual understanding.

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