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Conceptual continuity and the science of baseball: using informal science literacy to promote students' science learning

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Abstract This project explores *conceptual continuity* as a framework for understanding students' native ways of understanding and describing. Conceptual continuity suggests that the relationship between the use of words in one genre and the scientific genre can exist at varying levels of association. This perspective can reveal the varied relationships between ideas explained in everyday or vernacular genres and their association to scientific explanations. We conducted a 2-year study involving 15 high school baseball players' understanding of the physics involved in baseball. First, we conducted a quantitative assessment of their science understanding by administering a test prior to season one (2006) and season two (2007). Second, we examined the types of linguistic resources students used to explain their understanding. Third, we revisited our data by using *conceptual continuity* to identify similarities between students' conceptual understanding in the informal contexts and their similarities to canonical scientific ideas. The results indicated students' performance on the multiple-choice questions suggested no significant improvement. The qualitative analyses revealed that students were able to accurately explain different components of the idea by using a diversity of scientific and non-scientific genres. These results call attention to the need to reconstruct our vision of science learning to include a more language sensitive approach to teaching and learning.

Keywords Conceptual continuity · Discourse · Science language

Research has shown that learning discourse practices directly impacts science learning. Despite the rigor of that research, few explore how students' intuitive science learning is connected to the use of native discursive practices. Research has examined the grammar, rhetorical structure, and technical terminology of science discourse, but little science education research has compared the functionality of alternative genres of talk to science discourse.

Research on learning in informal settings has the potential to help science educators explore the relationship between formal and informal science discourse. Sociolinguists

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have argued that the linguistic resources available to people shape their cultural and intellectual behaviors. Some suggest the appropriation of different languages as an acquisition of an alternative worldview. As a result, if individuals are constrained to a singular discursive practice, they are necessarily locked into the worldview made available by their mode of discourse.

Scholars have suggested that a human's ability to conceptualize the world is connected to the medium of expression common to their culture (Sapir 1949). As a result, we can assume the native linguistic resources could be seen an unsupportive of those valued in science. This study frames native discourse use as an asset, as opposed to the deficit perspective that is prevalent in many studies. This may help teachers avoid viewing students' native discourse as a problem. Hammer argues that "much of naïve instructional practice is characterized by inappropriate presumptions regarding the resources students have available" (Hammer 2000, p. 53). We further suggest that much of the assumption about students' abilities are clouded by a naïve understanding of the value of students' discursive resources and hence, that science educators must learn to use the continuities embedded in students' native ways of understanding phenomena as a means to help them achieve a fundamental scientific literacy.

Unfortunately, equating proper science vernacular with understanding facilitates a right or wrong dichotomy and fails to acknowledge partial understandings that could serve as the foundation for future learning. In our attempt to explore students' conceptual understandings, we investigated the following questions: (a) How can the notion of *conceptual continuity* be useful in supporting our understanding of how young people comprehend science concepts? (b) What types of discursive resources are students using to explain their understanding of why a curveball curves? The following sections provide a detailed ethnographic examination of our interactions with student–athletes and their understanding of how a curveball curves. Traditional test scores as well as semi-structured interviews provide examples of students' understanding as explained through alternative discursive practices. These discursive practices lay the foundation for the final analysis of students' *conceptual continuities*.

Finding the right in wrong answers

Research regarding intuitive science understanding led to the development of learning theories describing how people come to understand the world. Posner et al. (1982) introduced and later revised a "conceptual ecology" as an overarching rationale for understanding how students come to understand a phenomenon. This framework, commonly know as conceptual change, explained how students advance from intuitive understandings towards reconstructed scientific understandings. Although conceptual change has been widely accepted as a theory for understanding student learning, it is not without its critics.

One of the primary critiques of this work involved claims about the limits of its effectiveness. Scholars argued that conceptual change is limited because it only describes learning that occurs when students hold a clear understanding of a phenomenon, thus, they argued for a more gradual alteration of students' perspectives. Others have argued that changing perspectives are gradual rather than drastic, while others argued that misconceptions are merely erroneous categorizations of concepts, which would make conceptual change a simple reassignment of concepts (Vosniadou 2002).

The idea that science concepts exist in stark discrepant contrasts was challenged by a number of scholars who argued for the recognition of students' native conceptual understandings. Some scholars have identified how conceptual change perspectives serve as foundational transformations between native understandings of the world and their scientific counterparts (DiSessa 2002). It is the challenge of reconciling the relationship between native conceptions and those valued by science that serves as the foundation of this study. If students develop complex understandings of the world in settings outside of science, then the ideas of conceptual change help scholars understand how scientific understandings are developed through alternative discourses. We take the position that using students' native ways of understanding the world as a means to help bridge their conceptual understanding has the potential to be fruitful to students' learning. However, we wish to add the additional dimension of discursive relativity to this analysis.

Precedent exists for student learning through conceptual continuities. DiSessa (1983) described how individuals transition from direct experience to scientific understanding by describing the role of continuities between intuitive and scientific understanding by writing,

> What we wish to take from Goethe is the sense that direct experience in only mildly altered form can play a significant role in the understanding of 'abstract' matters and his sense of continuity from naïve to scientific apprehension of the world.

We agree with this claim about the value of identifying emergent continuities between the "naïve" and "scientific." However, we would like to extend this perspective by adding the additional component of linguistic and discursive repertoires to the analysis of continuities.

Linguists have long argued that an individual's ability to conceptualize is directly connected to the culture of discourse made available (Whorf 1956). As individuals come to understand the world, they develop discursive practices that enable them to organize it. Without a perspective that accounts for the roles of alternative discursive repertoires in understanding learning, much of our understanding about students' conceptualization is limited to those instances where students are applying linguistic repertoires commensurate with science.

Exploring the language, identity, and learning paradox

To explore how students develop their own linguistic resources in understanding scientific ideas, we engaged in an ethnographic study of students' science learning at Stokley Carmichael High School. Carmichael is one of six high schools in a large urban school district in Northern California, USA. With a population of 400,000 people, the city is known for its diverse population. Stokley Carmichael's student population of over 1,500 students represents a changing local demographic, as over 60% of its students do not reside in the upper middle class neighborhood where the school resides. Most of residents in the school's local vicinity have children well beyond school age; therefore the majority of students at Carmichael are bused to school.

We examined how members of a high school baseball team described the physics of why a baseball curves to determine discourse uses and student conceptual continuities about the phenomenon. Of the members of the baseball team, 11 were African–American, 7 were Hispanic American, 7 were Caucasian–American, and 2 were Asian American. In addition to ethnic diversity there was a diversity of grade levels.

In 2006 six players were in the 11th grade, three were in the 12th grade, four were in the 10th grade and two were in the 9th grade. English was a second language for seven of the Hispanic–American players on the team. For the three Mexican–American players who participated in the research project, English was their first language.

About curveballs

Curveballs represent a unique physical phenomenon as well as a significant baseball strategy to prevent hitters from engaging in solid contact with the ball. Therefore, this important and frequent phenomenon served as the focal point for identifying student–athlete conceptual continuities. A curveball occurs when a pitcher throws the baseball with a particular spin to speed ratio that causes the ball to drop dramatically downward as it approaches the batter. If thrown by a right-handed pitcher, the ball will move down and away from right hand batters. Figure 1 shows an image of a curveball's movement. As the pitcher throws the ball, he attempts to generate as much torque as possible to generate a clockwise or forward spin. If spun correctly and with the appropriate amount of speed, the ball will travel forward, but will experience differential air pressure on the top and bottom half of the baseball. Due to the fact that the air on the top of the ball is traveling directly against the direction of the seams and the air on the bottom of the ball is traveling in the same direction as the seams of the ball, the top and bottom half of the ball will experience different levels of air pressure. This air pressure differential, or Magnus force, will cause the ball to experience a dramatic change in velocity as it slows. As a result, the ball will experience a dramatic move in the direction of the spin.

Skillful pitchers learn to generate this curveball movement in two ways. First, with a vertical spin, the pitcher can use the impact of Magnus forces to generate a rapid downward movement. In baseball terms, this is known as the 12–6 curveball. The numbers use a clock as a model for how the ball will change directions. A second way pitchers use this movement is to generate these Magnus forces at an angle. As a result, they can cause the ball to move from right to left (for right hand pitchers) and left to right (for left hand pitchers). In baseball terms this is known generically as a curveball or as a slider.

For non-pitchers, hitting a curveball becomes an essential component in becoming a competitive baseball player. As a result, one could assume that players hold an inherent interest in understanding how to hit a curveball and potentially how it works.

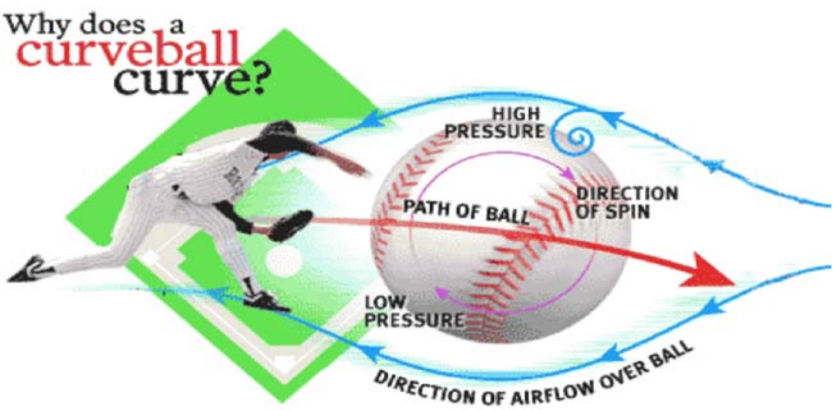

Fig. 1 Causal factors for a curveball

To assess this understanding, the first author interviewed the players and asked them to explain how a curveball moves in its flight to the batter. Later in the interview, the players were given a diagram (Fig. 1) that identified the general path of the ball, the direction of spin for a curveball, air pressure differential, and the direction of spin. The interviews were coded according to discourse features by identifying the discursive style—*science*, *everyday, baseball*, or *hybrid* for the previously mentioned. In addition, we administered the same test for year 1 and 2 that included 16 multiple-choice questions to assess what students could answer about why a curveball moves a particular way.

Examining students' native conceptions of baseball

The first author sought to examine students' understanding of physics through administering an identical test prior to season one (2006) and season two (2007). The test was designed to assess students' conceptual understanding as expressed in both science language and baseball language. Using his time as a participant observer, the first author identified numerous descriptive terms used by the team to explain phenomenon. For example, we asked the players "Which of the following best describes why a "hanging" curve ball hangs?" Alternatively, we asked, "Which of the following best describes what happens when a curve ball is thrown with great speed and little topspin?" Although these questions are not parallel, they attempt to assess students' conceptual understanding about how speed and spin impact the curveball's movement by asking similar questions in different discursive modes. The goal of this design was to offer questions that examined the same idea by using parallel genres of talk. In doing so we hoped to identify what students knew about why the ball behaved as it did, while also exploring how the choice of discourse used to ask the question impacted their ability to understand the concept.

Initial data collection began prior to the first baseball season in 2006. The research team visited the school and administered the multiple-choice examinations to gain understanding of students' knowledge of curveballs. Twelve of the players completed both tests. We also interviewed the students to determine their ability to describe the phenomenon. We used individual interviews to explore how students were able to express their understanding of why curveballs curve. The interview protocol offered questions about why curveball curves in parallel genres. The protocol was split into two components. First, questions were initially designed using science language. The second component of the protocol involved questions asked using the type of language documented by the researcher during the initial ethnographic component of this study. For example, one asked, "Please describe how the seams play a part in how the ball moves through the air when the pitcher attempts a curveball" This question was later followed with a more canonical question when the players were asked "Please describe how the seams affect the drag, velocity, and air pressure that affect the ball when a pitcher attempts a curveball" The second example was a summative question used to provide the players with an opportunity to express their understanding of curveball movement through the use of science discourse. The protocol was designed to ask questions in a variety of genres to provide access to students' conceptual understanding across the context of multiple discursive genres.

To provide a comparative data set we re-administered the test and administered the same interviews. We used the same protocol and administered the test prior to conducting the interview, just as we did in 2006. In both 2006 and 2007 the interviews were videotaped and transcribed for analysis.

Students' conceptions of why curveballs curve

The data revealed that students' informal understanding of curveballs paralleled some of the primary conceptual understandings commonly understood in physics. Although these answers did not adhere to current models of science language, the students' answers provided evidence of some aspects of their understanding of physics. First, we examine the students' conceptual knowledge over time via their performance on the test in year 1 and 2. Second, we examine the modes of discourse students used to explain why a curveball curves. Third, we used conceptual continuity to examine the differences in the types of continuities demonstrated in their descriptions in year 1 and 2.

Students' conceptual knowledge over time

Students involved in the test each year ($n = 10$) showed no statistical improvement in answering questions about the phenomenon of the curveball. As this study did not focus on learning that occurred about curveballs, this lack of change allows us to focus on the use of various discourse genres apart from changes in actual knowledge about curveballs.

On the pre-tests the students' averaged 7.3 correct answers (out of 16) compared to an average of 8.4 on the test in year 2. This approximately 1 point difference remains statistically insignificant especially considering the small sample size. Essentially, we were unable to use the testing to identify if students gained a greater conceptual understanding of the physics of baseball over a year.

Modes of discourse: a taxonomical review of discourse

Our second analysis utilized qualitative methods to examine the types of discourse used to describe curveballs. Students applied the use of four modes of descriptive discourse: (a) everyday discourse, (b) baseball discourse, (c) science discourse, and (d) hybrid discourse. Table 1 provides an overview of the four modes of discourse. For example, when using baseball discursive modes, students used terms like "falling off the table" and "break" to describe a curveball's movement. Words like "movement" and "bite" were also used to describe changes in directional velocity. The use of these terms provided examples of how students understood the difference between what scientists describe as "speed" and "velocity" without appropriating the scientific terms. The analysis that follows provides a more detailed taxonomy of the types of discursive language used to describe why curveballs curve. The players relied on each of these discursive resources to describe a curveball's movement.

Frequencies were generated using individual phrases as the unit of analysis in the context of a larger speech act. For example, a student may have used scientific and baseball related phrases within a speech act that were both coded individually. The context of the speech act was necessary, however, to determine how a student used a particular phrase. For example, a student could use the word "force" to mean an accelerating mass in the scientific mode of discourse or as something one is "forced" to do in an everyday language mode. Given the qualitative nature of this data, the frequency of their use of each mode of talk does not reflect statistical value, but is indicative of reemerging patterns. The sections that follow provide a detailed analysis of how students used each of these forms of talk.

Table 1 Modes of discourse

Cells	1 Frequency pre-interview	2 Frequency post-interview	3 Code name	4 Code description	5 Example
A	407	368	Everyday discourse	Instances where the player's descriptions of why curveballs curve involves the use of everyday (non-scientific/non-baseball) talk that is associated with baseball	Yeah, 'cause the—'cause when you throw the ball, the air is gonna hit the seams, so I guess that's the main point of making the curve ball
B	112	110	Baseball discourse	Instances where the player's description of why curveballs curve involves the use of genre-specific talk that is associated with baseball	If you throw a curve ball, the seams cutting through the air, it's gonna cut down
C	81	115	Science discourse	Instances where the player's description of why curveballs curve involves the use of science terms to explain why a curve baseball curves	So I guess probably the top one's high pressure and the bottom one's low and it's pushing it down so that it looks like it's curving
D	2	4	Hybrid discourse	Instances of talk where students explain science concepts using both blended versions of either science and baseball words or science and everyday terms associated with baseball to explain phenomenon	It doesn't break at all. I mean, it hangs—it actually didn't break because it had enough spin like a front spin on it so it would drop

Everyday discourse

Student–athletes made extensive use (407 instances in the pre-interviews and 368 instances in the post-interviews) of everyday discourse in describing the phenomenon of a curveball. Everyday language included conversations not rooted in baseball or scientific discourses—words accessible to the general public. Words or phrases coded as everyday discourse would include such general terms as push, pull, air, wind, fast, and slow. Therefore, speech acts utilizing common words and phrases to describe a curveball were coded as everyday discourse.

For both pre-season and post-season interviews across both years, we performed a more fine-grained analysis developing a six-category taxonomy shown in Table 2. Students applied their everyday language resources to describe the following concepts using common language: air pressure, changes in velocity, directional terms, force, spin, and wind influence. Cell 5-A describes instances in which students incorporated the concept of air pressure using everyday language ($n = 120$, 113). For example, one student stated, "When you snap your wrist, it forces the ball to spin like this, and then air will continue to push it against the seams." The student recognized that air represents an agent of force, in this instance "pushing" against the seams.

In one pre-interview, Sam used an everyday genre of discourse to explain the air pressure differential placed on the ball. Sam explained, "I don't know if it's high or low, but one of them is on the top and one of them is on the bottom—the top one's pushing it down in kind of an arc and the one on the bottom can't hold up to it."

Student–athletes also used general language in describing directional changes (cell 5-C). This included terms like "down," "up," and "slanted."

As previously mentioned, student–athletes incorporated force representations in their discourse by using simple terms of "push" and "pull." Cell 5-D illustrates an even more subtle representation of this concept when one player described a ball going through the air saying, "[It] is the space—the resistance coming like—it's meeting it like—wind is meeting it like that." In this case he has attributed the force of the wind on the ball in terms of both "resistance" and "meeting it." The theme of wind and air was used frequently in discourse ($n = 40$, 14). In some instances wind and air were used not in reference to the pressure it exerted on the ball, but in general terms as a medium through which the ball traveled. Other students, as seen in cell 5-F, referenced wind in terms of general weather saying, "[I guess] it can also depend on what kinda weather you're having and I guess what kinda air—like the wind is faster or something like that."

Students made extensive use of spin in their descriptions of a curveball ($n = 113$, 150). Cell 5-E provides a typical example in which a student stated, "So like if you snap your wrist hard, then the top spin is going to be fast."

Comparison of everyday discourse in year 1 and 2

Looking more closely at the disaggregated frequencies, the pre-interview analysis indicates a heavy reliance on everyday language resources to describe the concepts of air pressure (*pre* $n = 120$, *post* $n = 113$), changes in velocity (*pre* $n = 82$, *post* $n = 73$) and the role of spin (*pre* $n = 113$, *post* $n = 150$). Overall, the post-interview data shows little difference in the relative distribution among the terms. While no causal explanation for shifts in relative frequencies can be made, it is interesting to note that everyday discourse practices were used consistently in year 1 and 2. The sole exception can be found in the manner in which

Table 2 Everyday discourse—frequencies for year 1 and 2

Cells	1 Frequency pre-interview	2 Frequency post-interview	3 Code name	4 Code description	5 Example
A	120	113	Air pressure	These are descriptions in which students describe the role of air pressure on the ball using everyday language	"When you snap your wrist, it forces the ball to spin like this, and the air will continue to push it against the seams"
B	82	73	Changes in velocity	These are descriptions in which students describe the changes in the ball's velocity using everyday language	"It actually comes—I mean like it comes in slower—slower speed. Comes in slower speed and actually breaks"
C	23	20	Directional terms	These are descriptions in which students describe the ball's direction using everyday language	"And then for a curve ball it's kind of slanted more down like that kind of, you know"
D	4	11	Force	These are descriptions in which students describe the ball being moved by its interaction with the air using everyday language	"A is the space—the resistance coming like—it's meeting it like—wind is meeting it like that"
E	113	150	Spin	These are descriptions in which students describe the role of spin on the ball using everyday language	"So like if you snap your wrist hard, then the top spin is going to be fast"
F	40	14	Wind influence	These are descriptions in which students describe the role of the blowing wind on the ball using everyday language	"Guessing it can also depend on what kinda weather you're having and I guess what kinda air—like the wind is faster or something like that"

students used everyday discourse to explain the concept of spin more often in the second season ($n = 150$) when compared to season one ($n = 113$).

Science discourse

In our use of the term "science discourse" to codify students' language, we do not intend to suggest that the students are applying scientific discursive behaviors in a broad sense (e.g., symbols, grammar, inscriptions, and representations). Instead, we are differentiating between the types of descriptive terms used in their discussion of curveballs. In order to code descriptors according to this framework, we differentiated between terms used in a generic sense and terms with specific scientific definition. Sometimes those words can actually be the same word applied in different contexts. One could say, "I was 'forced' to apply for this college." In this sense, the term is used in a generic fashion to suggest influence or persuasion. As mentioned above, this instance would not be coded for science discourse. When we coded terms as "scientific," we would only code the use of the term "force" if it describes the influence of mass times acceleration.

The students used a variety of science descriptors including drag, force, air pressure, and velocity. Unlike everyday discourse in which we performed a finer grain analysis to relate the everyday words to the intended scientific meanings, the use of scientific discourse upfront makes this type of taxonomical analysis irrelevant. However, we were able to analyze at greater depth how students used this form of discourse. Table 3 provides an overview of the seven types of re-emerging types of science discourse used in their descriptions.

Students engaged in comparative uses of science discourse (cell 3-A). These were instances where students' science talk included their comparing the science terms with other descriptors from a genre other than scientific ($n = 2, 2$). An example of this is offered in cell 5-A as (D'Angelo) described the role of drag by explaining, "And the drag is what takes the [curve] ball, so basically the power [placed] on the curveball." Here, he describes how the concept of drag is responsible for the curveball comparing it to the "power" placed on the ball.

We also coded instances of talk in which players appropriated a science term, but failed to apply it with an accurate meaning (cell 3-B). For example, one student explained, "the velocity on the ball and the pressure on top as well as the bottom of the ball make it move." In this instance, the term velocity is used as analogous to the concept of speed. Players also appropriated science terms accurately ($n = 54, 13$). These were instances where students provided descriptions of a curveball where they used a science term correctly ($n = 9$).

Another mode of discourse involved the student-athlete erroneously using science discourse in an explanation. These feigned uses of science discourse are episodes of students' science talk where students attempted to use science terms without understanding it ($n = 13, 18$). An example of this can be found in cell 5-D of Table 3. Reggie explained the role of drag by stating, "It affects the drag by—I'm not really sure." This is an example of how students would say a science term without truly understanding the concept associated with it.

Many of the uses of science language occurred when students were describing the image of a curveball that was provided during the interviews. We coded these instances of talk as instances of image application. For example, one student wrote, "And B is pointing to deflected wake, and I'm guessing that means, it stands for a fast ball, meaning that [the ball] is deflected and that a regular ball that is thrown, maybe fast ball, yeah, something like that." In this example, the student is referring to an image that has a picture of two

Table 3 Science discourse—frequencies and code descriptions aggregated for years 1 and 2

Cells	1 Frequency pre-interview	2 Frequency post-interview	3 Code name	4 Code description	5 Example
A	0	2	Comparative use	These are episodes of students' science talk where students compare science terms with other descriptive terms and concepts	"And the drag is what takes the ball, so basically the power on [curve], the curve"
B	5	3	Alternative meaning	These are instances of talk where the speaker uses a science term, but uses it in an incorrect or alternative manner	"The velocity on the ball and the pressure on top as well as the bottom of the ball all combined make it move"
C	54	13	Accuracy	These are episodes of students' science talk where students appropriate the science term in the appropriate context	"When the ball's spinning, the air resistance or the drag will be less because of the spinning ball parting air"
D	13	18	Feigned use	These are episodes of students' science talk where students attempt to use a science term, without understanding it	"It affects the drag by—I'm not really sure"
E	5	13	Image application	These are episodes of students' science talk where students use a science term in the description and analysis of a science image	"And B is pointing to deflected wake, and I'm guessing that means ñ stands for fast ball, meaning that it's deflected and that's its a regular ball that's thrown, maybe fast ball, yeah, something like that"
F	2	7	Lexical metaphor	These are episodes of students' science talk where students use a science term in a metaphorical context	"The same thing; the air currency and how it catches the seams"
G	1	25	Multiple application	These are episodes of students' science talk where students use a science term for multiple purposes and with multiple meanings	Version 1: "The air pressure affects the curveball and the high pressure affects the curveball by the direction it pushes the seams back which makes the ball drop down." Version 2: "You control the pressure you put on the ball, and the spin you put on the ball"

baseballs and references the wake of the ball's movement. We coded instances like these where students appropriated science language based on their use of an image in a category that isolated those instances where science talk was used in direct relation to their assessment of a scientific image ($n = 5$, 13).

Another mode of science talk was coded under the heading of lexical metaphor (Halliday and Martin 1994). These are episodes of students' science talk that use a science term in a metaphorical context ($n = 2$, 7). For example, one student describes how the ball has an "air currency" and how that air currency "catches the seams." He may have merely mispronounced the term current, but given the fact that our analysis is descriptive rather than causal, we coded instances of talk where students used science terms in a metaphorical context under the code title of lexical metaphor.

A final category of science talk involved students' use of science terms with multiple meanings. This occurred most often with their use of the term pressure. In one instance "pressure" was used to refer to the force the air placed on the ball. For example, one student stated, "The air pressure affects the curveball and the high pressure affects the curveball by the direction it pushes the seams back which makes the ball drop down." In another instance, these same students use the term "pressure" to describe the force the pitcher places on the ball with his fingers. For example, he explained, "You control the pressure you put on the ball, and the spin you put on the ball." We coded these instances as using science discourse with multiple meanings ($n = 1$, 25).

Comparison of science discourse in year 1 and 2

As we compared students' use of science discourse over the course of a year, we noted the similarities and differences in how students were able to use science discourse over this time period. First, we noted that students used science discourse more accurately in year 1 ($n = 54$) than in year 2 ($n = 13$). Inversely, in year 1 students feigned the use of science discourse less ($n = 13$) than in year 2 ($n = 18$). Table 3 provides an overview of the post-interview results.

Overall, the results suggest that over the course of the academic year, students acquired little to no additional understanding regarding why a curveball curves as expressed in science language. This is supported by the pre- and post-season multiple choice tests for both years. In fact, students demonstrated a decreased ability to appropriate science language in the course of providing their explanations. These results are not surprising given the fact that science discourse was rarely used during their baseball instruction and play.

Baseball discourse

One of the primary modes of discourse used by the players involves their use of language coded as "baseball language." Baseball language identifies the use of language that was specifically used to describe concepts in baseball. In many instances, the meaning of a term was different in the case of baseball than in more generic contexts. Some examples of how students used baseball terms included using terms like "velocity," and "falling off the table." We identified these terms in the ethnographic component of our study and identified how students' used "velocity" to describe the speed at which the ball was thrown. Additionally, the term "falling off the table" was used to describe the dramatic change in directional velocity that occurs when a curveball begins to move. Students were able to use these intellectual resources associated with baseball language to describe the phenomenon of curveballs.

Consistent with our previous analyses, we were less focused on what words were used and more concerned with how these student–athletes were able to use baseball discourse to describe the movement of curveballs. Table 4 provides an overview of the types of baseball discourse used that relate to the scientific phenomenon. One of the ways baseball language was used to describe the physics of a curveball was in the description of how the ball changed its directional velocity. In the pre- and post-interviews there was a total of 84 (pre) and 53 (post) instances where students used baseball language to describe air contact and its impact on the curveball's movement. Cell 5-A provides an example of this code as Nate explained, "for a curveball to work, you got to put a lot of rotation on it so it spins enough so it breaks." In this example, he uses the term "breaks" to describe how the ball changes direction. The term break is a term commonly used in baseball to explain how a baseball rapidly changes directions.

Cell 5-B offers another example of baseball language. In this example of how baseball language was used to explain changes in directional velocity, Scott uses a name of a baseball pitch to explain a particular type of ball movement. Scott explains, "A knuckleball really doesn't have not spin at all, that's the purpose of the knuckle [ball]."

One of the ways players used baseball language was to differentiate between the concepts of speed and velocity (Cell 3-C). This was an intriguing result, given the fact that students often made a distinction between the notions of speed and velocity (*pre* $n = 11$, *post* $n = 22$). Although they did not use the traditional terms "speed" and "velocity," these student–athletes were able to differentiate between these concepts through the use of baseball terminology. For example, one student described the need for adequate speed on a curveball by explaining, "the ball should have a good, and you know, velocity to it." In his use of the term "velocity" he was not referring to velocity in the more scientific sense that refers to the rate of change. Instead, the students used the term "velocity" to refer to the speed of the ball and the term "movement" to refer to the rapid change in direction a ball experiences. Students' use of baseball language as a means to differentiate between speed and velocity (in the scientific sense) provided them with linguistic resources from which to understand how these concepts impact the physics of curveballs.

What became clear in our analysis was the fact that the players were able to use the discourse of baseball to describe how a baseball experiences a change in velocity. In addition, they were able to use baseball language to differentiate between the speed of a baseball and its changes in velocity. Given the fact that much of the strategy involved in the game of baseball includes a pitcher constantly changing the speed and velocity of the baseball, the discourse of baseball included linguistic devices that allowed the players to make those types of distinctions. As pitchers, catchers, hitters and defenders discuss hitting and playing defense, the language of baseball includes the discursive tools to enable them to make unique differentiations between the types of movement experienced by the baseball.

Comparison between year 1 and 2

When conducting a comparative analysis of the players' discussions of curveballs in year 1 and 2, we noted how the players placed a great deal of emphasis on how the air affected the seams. In general, the players showed similar discursive behavior in year 1 and 2. However, the players did not rely on baseball language to explain changes in velocity in year 2 as much as they did in year 1. In year 1, the players used baseball discourse to describe changes in velocity on 84 occasions; while in year 2, they used baseball language to explain differences in velocity on 53 occasions.

Table 4 Pre-analysis baseball discourse—level 2 frequencies and code descriptions aggregated for years 1 and 2

Cells	1 Frequency pre	2 Frequency post	3 Total	3 Code name	4 Code description	5 Example
A	84	53	137	Changes in velocity	These are instances of talk where students use baseball talk to describe changes in velocity	"For a curve ball to work you got to put a lot of rotation on it so it spins enough so it *breaks* and it's not on a straight line."
B	7	2	9	Naming pitches	These are instances of baseball talk where the students use baseball language to label the different types of pitches	"A knuckle ball really doesn't have no spin at all—that's the purpose of the knuckle. It doesn't just catch the wind and the seams don't move at all."
C	11	22	33	Speed vs. velocity	These are instances of talk where students use baseball terms to differentiate between speed and velocity	"The knuckle ball has no *movement* on it, but it goes up and down because the air catches those couple seams."

Our resulting analysis provides a clear vision of how the language of baseball supports the cognitive differentiation between the notions of velocity and speed. Given the fact that these concepts are inherently connected to a player's performance, the players were able to apply baseball language to make those distinctions.

Hybrid discourse

Hybrid discourse, instances when players blend multiple discourse genres, represents the final mode of student discourse (Table 5). We coded discourse as hybrid only in instances where the players used one mode of discourse immediately following a different genre of discourse. Many times the students switched genres to provide qualifiers that further explained the same concept by employing an alternative genre. Cell 4-A provides a description of hybrid talk we coded as everyday to baseball talk. These were instances of talk where the speaker used everyday discourse first, then followed that discourse with baseball discourse. For example, one student explained:

> If you have less wind pressure, which means like if you throw [the ball] with less velocity then you won't have a curveball. You'll have a curveball but it won't curve much.

This is an instance where the student described the effect of wind pressure by first using the word wind pressure. He then qualifies the statement by describing how the ball will be thrown with less velocity. In this instance, the player used the everyday term wind pressure to describe air pressure, but then uses a baseball term velocity to describe how the speed of the ball is responsible for the amount of "wind pressure" placed on the baseball.

Another example of this involves instances of players using everyday discourse followed by science discourse (4-B). These were instances of talk where the speaker used everyday discourse first, then followed it with a scientific alternative. For example, one student explained, "a curveball moves because of how the wind or the air currency hits the seams." In this instance, the student used terms "wind" and "air current" synonymously.

A final example of hybrid discourse involved the use of science discourse that was then supported by the use of baseball talk (3-C). For example, a student explained, "If you have less wind pressure, which means like if you throw it with less velocity, then you won't have a curveball." In this example, the player used the term velocity to describe the ball's speed to support his assertion about how speed impacts the air pressure experienced by the ball. This student nearly repeated an instance of his hybrid discourse described earlier as he demonstrated a patterned use of this mode of discourse.

Comparison between year 1 and 2

When comparing the students' use of hybrid discourse across academic years, we noted how the use of blended genres of talk remained rare in students' descriptions. Ultimately, the players were not prone to using multiple genres to describe the phenomenon associated with throwing a curveball. Overall, students' use of hybrid discourse was limited and did not serve a significant component of students' discursive practices.

Conceptual understanding from a conceptual continuity perspective

The collective results of our above analyses did not demonstrate learning gains. In an effort to explore how viewing understanding as an issue of continuities benefits science

Table 5 Hybrid discourse—frequencies and code descriptions for years 1 and 2

Cells	1 Frequency pre	2 Frequency post	3 Code name	4 Code description	5 Example
A	1	1	Everyday to baseball	These are instances of talk where the speaker uses everyday discourse first, then follows them with a baseball alternative	"If you have less wind pressure, which means like if you throw less velocity then you won't have a curveball. You'll have a curveball but it won't curve as much"
B	0	1	Everyday to science	These are instances of talk where the speaker uses everyday discourse first, then follows them with a scientific alternative	"A curveball moves because of how the wind or the air current hits the seams"
C	0	1	Science to baseball	These are instances of talk where the speaker uses science discourse first, then follows them with a baseball alternative	"If you have less wind pressure, which means like if you throw it with less velocity then you won't have a curveball"

educators, we revisited the previously described data. However, when a *conceptual continuity* framework is applied, we are better able to identify the types of conceptual continuities displayed over the course of the year. Specifically, students demonstrated a greater understanding of how pressure differential impacts ball movement. In conducting this analysis, we coded for instances where students' answers were completely correct or instances where components of a student's answer were correct. We coded on the level of both cognitive conceptual continuities and linguistic conceptual continuities.

In year 1, Arthur explained, "That's what the seam is for—the seams catch the wind, and so when the seams catch the wind, it affects the rotation of the ball." After a year, his post-interview included a more detailed explanation as he explained, "The air pushes the seams on top and bottom differently. It basically, goes with the bottom one and against the top ones, so the ball drops really fast at the end." This accurate explanation of differential air pressure reflects a more detailed understanding. From our position, his explanation offers what we describe as a "cognitive" type of conceptual continuity. Although this explanation does not include terms like air pressure, Magnus forces, or drag, it does accurately describe components of the ideas, and thus maintains a level of conceptual continuity with the correct idea. This excerpt reflects how Arthur has learned additional components of the ideas of the concept, but has yet to learn the scientific language—a cognitive, but not necessarily linguistic continuity. More specifically, using this framework allows us to understand how changes in the type of continuity are fruitful for his learning.

A second finding involved students' demonstration of improvement in the types of conceptual continuity. Table 6 provides an overview of the coded types of conceptual continuities. In year 1, most students failed to recognize the impact of the air pressure differential on either side of the baseball. This differential, often called Magnus forces, emerged as a key learning outcome in year 2 as it was explained in detail on 9 occasions (4-E). In this way, students demonstrated paralleled linguistic conceptual continuity as they developed a clear definition of the science terms that were described using non-scientific language.

Another example involved how students changed perspective about the role of air pressure on why a curveball curves. For example, one student described his understanding of the role of air pressure by explaining, "the air pressure might be moving it a little bit." These descriptions of the role of air pressure were more prevalent in year 2 ($n = 75$) than in year 1 ($n = 47$). Although a more accurate description may include a detailed description of air pressure differential, or the Magnus Effect, a conceptual continuity perspective identifies how these players developed a more nuanced understanding of how air pressure impacted the ball's movement. Such a change reflects a growth in the cognitive conceptual continuities students maintained in year 1 compared to year 2. This increase provides a sense of how changing our understanding of science knowledge as simply right or wrong towards a perspective that illuminates conceptual continuities shows how components of students' understanding have grown.

Students demonstrated the greatest number of conceptual continuities in their descriptions of how air pressure impacted the curveball's movement (cell 4-A). Although no one specifically described the curveball's movement in term of Magnus forces or air pressure differential, students held a common understanding that air pressure was responsible for why the curveball moved the way it does. An example of this type of continuity type was found as one student explained, "[A Curveball] might curve because of the way that he might hold it. If he snaps his fingers, the air pressure might be moving it a little bit." Although this answer is expressed with tentative understanding, it reflects how students held an intuitive understanding that the air pressure could explain a curveball's movement.

Table 6 Types of conceptual continuity frequencies and code descriptions for years 1 and 2

Cells	1 Frequency pre	2 Frequency post	3 Total	4 Code name	5 Code description	6 Example
A	28	47	75	Air pressure	These are instances where the player describes the role of air pressure in the analysis of why the curveball curves	"It might curve because of the way that he might hold it. If he snap his fingers, the air pressure might be moving it a little bit."
B	7	33	40	Speed and velocity	These are instances where the player describes the role of 'speed' or 'velocity' in the analysis of why the curveball curves	"The air you see, it depends on how fast you throw it, since the speed, I guess, when speed [of the ball] hits the air, it pushes the air I mean, the air pushes the ball this way, meaning the ball, it spins, and then when the ball is spinning when the air pushes the ball, it pushes the ball down because the pressure to blow it down, and the ball goes down."
C	0	25	25	Air and seams	These are instances in which the player cites the interaction of air or wind with the seams as a cause for why a curveball curves	
D	10	11	21	Movement	These are instances where the player describes the role of "movement" in the analysis of why the curveball curves	"A hanging curveball is a curveball with no movement. It just stays waste high, which allows a hitter to turn on and hit it outta the park."
E	3	6	9	Magnus forces	These are instances where the player describes the role of Magnus forces in the analysis of why the curveball curves	"Because when [a curveball] is thrown and when it is released out of the thrower's hand, half of the ball would have more air going on it and there would be the resistance on like half of …I mean, one side of the ball would be different than the other going through air. And so, of course, the ball would drop."
F	13	11	24	Drag	These are instances where the players describe how Drag impacts the curveball's movement	"Drag can affect a changeup. When you throw the changeup, the baseball is slower, and usually most changeups that are we will slow down and kinda fall a little bit, just drop a little bit for hitters to hit it down to the ground."

Again, this represents a cognitive conceptual continuity that elicited some, but not all components of the curveball phenomenon.

Another commonly held continuity is found in students' generic descriptions of the role of air on the baseball. On 47 occasions, students described the air as responsible for the baseball's movement.

> Well, when you flick the ball, it cuts through the air. It has different airs under it and over it and starts pressing it down so it drops and the air on the bottom is more loose in the right way and it just the heavy pressure makes it drop.

This example provides an intriguing insight into the types of conceptual continuities held by students. The student explains how the ball has "different airs under it and over it." Although the student does not accurately describe these "airs" as differences in air pressure or describe this movement in terms of drag or Magnus forces, he seems to capture the fundamental aspect of the ball's movement. Given the fact that the baseball's movement is caused by the air pressure differentiated from the spin of the ball producing higher levels of air resistance on the top of the baseball than on the bottom, his description provides a tenuous understanding of the concept without having the scientific terms available as an additional conceptual resource. One could argue that this also reflects a linguistic conceptual continuity.

Another type of continuity involved their continued references to the role of the seams in producing the movement (4-C). These descriptors were of two types. First, the student–athletes described how the seams were responsible for producing the spin when the ball was thrown. Second, and perhaps more abstract, the students described how the seams were responsible for the differential air pressure that the ball experienced. For example, Samuel explained how the seams produced a bit of air resistance as he explained the following:

> When you snap your wrist, it forces the ball to spin like this, and the air will continue to push it against the seams. The way that it pushes against the ball will make it curve inward or just curve in general.

Although this description of why the curveball curves does not adequately explain the complete phenomenon, it does indicate a rich understanding of how the seams play a role in producing air pressure on the baseball when a curveball is thrown. In general, there were 44 instances of conceptual continuities involving students providing a description of the role of the seams and laces on the baseball's movement.

Table 6 provides several other examples of the types of conceptual continuities exhibited by students. Cell 4-B describes the 16 instances in which students demonstrated their understanding of the role of speed and velocity on the curveball's movement. One player explained:

> The air you see, it depends on how fast you throw it, since the speed, I guess, when speed [of the ball] hits the air, it pushes the air I mean, the air pushes the ball this way, meaning the ball, it spins, and then when the ball is spinning when the air pushes the ball, it pushes the ball down because the pressure to blow it down, and the ball goes down.

This is an example of how students were able to describe the impact of speed in producing greater air pressure differential. Although the students demonstrated a vague understanding of this impact, a conceptual continuity framework would emphasize the parallel relationship between their description of the ball hitting air and the science understanding of the role of air pressure and resistance.

There were other continuities that demonstrated more nuanced understandings of the concept. The players' description of speed and velocity (Cell 4-B), and movement (4-D) both indicated their understanding of the distinctions between linear movements, changing speeds, and rapid changes in directions. As stated above, much continuity involved their ability to identify the ideas of Magnus forces. Although students were unable to use the terms "Magnus forces" several students ($n = 9$) were able attribute the baseball's movement to the result of differential air pressure forces on either side of the baseball. This represents a parallel conceptual continuity, as the conceptual meaning is equitable across differing genres of discourse; the words used to describe the phenomenon are different. For example, one student explained how the top of the baseball has "air always pushing against it to slow it down." He then contrasted the air pressure on the bottom of the ball by explaining how the ball has "more air rolling off and the less air resistance there to stop it from going faster". Although his answer lacks the use of specific science discourse that would enable him to differentiate between the types of pressure or describe the forces in terms of Magnus forces, he has a clear understanding of how the air pressure differential impacts the ball's movement. In another statement he offered a similar explanation by explaining:

> Because when [a curveball] is thrown and when it is released out of the thrower's hand, half of the ball would have more air going on it and there would be the resistance on like half of …I mean, one side of the ball would be different than the other going through air. And so, of course, the ball would drop.

Here again he offers an explanation that provides a nuanced understanding of the role of air. From a cognitive perspective, much of what he is able to articulate about the relationship between the ball and the air provides evidence of his cognitive schema lacking essential dimensions of conceptual understanding. From a conceptual continuity perspective, we can see that there is a strong parallel continuity between his understanding of air pressure differential as expressed in everyday language and the idea of Magnus forces or drag.

Another type of conceptual continuity we encountered involved their descriptions of the concept of velocity. We coded for 9 instances where students described differences in the directional velocity of a baseball by using the baseball phrase "hanging curveball." For example, James explained the impact of speed on the baseball and its ability to rapidly change. He explained, "if you have less velocity then, yeah, then it's just gonna be a like a hanging breaking ball or it's not gonna curve as much." In this instance, he provides a description of how the curveball's ability to change direction is a function of the speed at which the baseball is thrown. Although he used the term "velocity" to refer to speed and then uses the baseball term "hanging breaking ball" to explain this difference, he offers his tenuous understanding of the relationship between speed and the ball's ability to experience a rapid change of vector velocity.

A final instance of conceptual continuity demonstrated by the players involved the concept of drag.

> Drag can affect a changeup. When you throw the changeup, the baseball is slower, and usually most changeups that are will slow down and kinda fall a little bit, just drop a little bit for hitters to hit it down to the ground.

In this example, the player attributes the drop involved with a changeup to the amount of drag placed on the baseball. Although most of the references to drag were found when students were either asked about it or when they were explaining the diagram, there were some instances where students demonstrated an understanding of how drag impacted the ball's movement.

Changes in continuity type in year 1 and 2

Overall, we have identified a variety of students employing alternative genres of discourse that maintain conceptual continuity with science discourse. In fact, as we applied the conceptual continuities lens to examining their responses, we identified that students developed a rich understanding of how air pressure differential impacts the curveball's movement. Additionally, students seemed to offer complex understandings of how the wind interacts with the baseball to affect its behavior. The students also demonstrated a detailed understanding of how the seams of the baseball impact the ball's behavior when a curveball is thrown. This perspective identifies some clearly articulated conceptual understanding that is expressed using a variety of discursive modes including those that are a part of playing the game of baseball.

Building from binary discourse towards conceptual continuities

This analysis provides a theoretical lens for scholars to re-conceptualize how students come to understand scientific ideas. We argue that viewing students' science understanding through two modes of conceptual continuity: (a) conceptual continuity as cognitive and (b) conceptual continuity as linguistic provides descriptive evidence of how students' understanding exists at varying levels of continuity with science ideas. These continuities are critical in enabling students to use their native ways of understanding the world in meaningful ways.

What emerged as interesting in this analysis was the manner in which the language of baseball served a similar function to the language of science. First, the baseball language used by the student–athletes in this study included specific conceptual language that provided them with ways to differentiate between scientific ideas. According to the Sapir-Whorf hypothesis, this notion of native language practices having the ability to provide individuals with cognitive resources is consistent with ideas explored in linguistic research (Whorf 1956). As individuals affiliate and organize their worlds, their discursive practices must afford room for modes of cognition. Said differently, if individuals need language to provide metaphysical or taxonomical ways of understanding the world, their discursive resources should provide them with the resources to make those distinctions using culturally specific discourse. Consistent with this perspective, the language practices in the sport of baseball provided the student–athletes with the resources needed to make the distinctions between key scientific ideas (e.g., velocity and speed). These represent the linguistic continuities between baseball and scientific discourse. Furthermore, just as science discourse involves complex sets of ideas, the data revealed how students developed detailed cognitive continuities—understandings of components of scientific concepts as a part of learning. Table 7 demonstrates how students developed detailed understandings of science concepts through learning the sport of baseball. This table shows how the baseball context and discourse enabled them to thoroughly grasp two fundamental concepts of the physics that explains why a curveball curves. As indicated in Table 7 the players developed a complex understanding of the relationship between the seams and the baseball as

Table 7 Continuity of science terms and concepts

Baseball register	Description	Science equivalent	Analysis
Linguistic			
Movement	Players defined movement as the sudden movement or change in direction of the baseball as it travels towards the plate	The term "*velocity*" is a more appropriate term in that it addresses the change in direction of an object	Although the players use the term "movement" where science would use the term "velocity", players are able to make a distinction between the speed of an object and its movement
Velocity	Players used the term velocity as a way to describe the speed the ball traveled from the pitcher to the plate	The term "*speed*" would be more appropriately applied in science to explain the ratio of distance per time interval	Similar to the above, the context of baseball provides access to two ideas regarding movement: per time and change in direction of a moving object
Conceptual			
Spin to speed relationship	Players suggested the curveball's movement was due to the rate of spin and the pressure produced by the spin to speed ratio	A scientific account of the curveball would indicate the forces responsible for the movement of the ball (Magnus forces/Drag) is associated with the differential relationship between the pressure on the top and the bottom of the baseball	The players uniformly understood a basic concept of the spin of the ball altering the ball's trajectory
Seams to air and resistance	Players reiterated that the seams met with air to produce a force that pushed the ball down	The aerodynamics of the ball is greatly altered by the seams. If the seams are spun at an appropriate angle, the seams generate air pressure as they interact with the passing air	The emphasis on the seams implicates the shape of the object with producing the desired aerodynamic

well as a rich understanding of the relationship between air resistance and the seams of the ball.

The importance of this study crosses theoretical, professional development, and empirical grounds. From a theoretical perspective, the results call attention to the need to consider *conceptual continuity* as a framework for understanding students' science learning. These findings have the potential to restructure contemporary theories of science learning by challenging the paradigm of teaching from an assessment of right and wrong answers towards teaching that accounts for demonstrations of levels of conceptual continuity.

From an empirical standpoint, the findings call to question the need to see scientific words and scientific concepts as distinctively different. Lastly, the results of this study have implications for teaching and professional development. Applying conceptual continuity as a teaching approach requires the teacher to use formative assessment opportunities to identify layers of correctness. Such an approach would make the design of classroom environments radically different.

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