Sports Experiences as Funds of Knowledge for Science: College Students' Ideas about Science in American Football

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Abstract

Physics and physical science content are essential for many professional fields, and they are an important component of scientific literacy. Yet, students are commonly less engaged in physics learning at all levels. Funds of knowledge approaches to science instruction build upon learners' real-world experiences and interests in order to make science learning more relevant and engaging. This study investigates how college undergraduates' football experiences elicit physical science content knowledge with a larger goal of developing physical science instruction that better connects to learners. This exploratory interpretive study utilized individual interviews and a focus groups with 22 college students to elicit their ideas about a variety of common football contexts: kicking, pursuit, throwing, and football deflation. The analysis identified several physical science concepts elicited by particular football scenarios, particular football experiences that could be utilized in science instruction, and some misconceptions or points of confusion about physical science concepts. Implications for curricular development, teacher education, and research are provided.

Keywords: American football, funds of knowledge, physics education, college science

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Introduction

Physics and physical science content are essential for many professional fields, and they are an important component of scientific literacy (Bybee, 2002). Yet, students are commonly less engaged in physics learning at all levels. From the 2011 TIMSS report (National Center for Education Statistics, 2011), eighth grade students indicate that they "like physics" (67% agreement) much less than that they "like biology" (78%). Similarly, eighth graders' selfperceived abilities are worse in physics: 68% indicated that they "can do well in biology while only 58% indicated that they "can do well in physics."

Physics is important for scientific literacy and yet its mastery is elusive for many learners. One way to connect physics content to science learners is to base instruction on real-world phenomena, anchoring events, that puzzle students and require the development and refinement of explanations (Stroupe, 2017; Windschitl, Thompson, Braaten, & Stroupe, 2012). Funds of knowledge approaches acknowledge the real-world experiences that learners bring into the classroom and offer a possible entry for otherwise disengaged physics learners. The present study asserts that students' real-world sport experiences can serve as funds of knowledge for learning physical science content. Sensitive to these funds of knowledge, physical science teachers may be able to capitalize on students' relevant experiences to better engage learners.

The Next Generation Science Standards (NGSS) (Achieve, 2013) include several physical science concepts that can be connected to American Football experiences at the middle and high school levels. First, Newton's second law is a Disciplinary Core Idea that appears at the high school level. In HS-PS2-1 Motion and Stability: Forces and Interactions, students are expected to "analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration." In this case, the American football could be such a macroscopic object. Also, the HS-PS2-2 Motion and Stability: Forces and Interactions standard encourages students to "use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system." These mathematical calculations could be performed regarding the momentum of a kicked football. At the middle school level, thermal expansion and gas laws appear in MS-PS1-4 Matter and its Interactions, inviting students to "Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed." The temperature-dependent deflation of footballs can serve as a context for this model development. Thus, the Disciplinary Core Ideas in the national document are relevant to the context of football.

In this study, we start with common American football contexts familiar to many American college students to identify what funds of knowledge can be elicited. These funds of knowledge can be drawn upon for future science curriculum development and also represent an opportunity for science education researchers to more broadly consider how students' funds of knowledge can ascertained.

Funds of Knowledge

Funds of knowledge are the "strategic and cultural resources" (p. 313) learners bring with them from their households and family experiences (Velez-Ibanez & Greenberg, 1992). This cultural metaphor serves as an alternative to deficit views of culture that emphasize children's deficiencies rather than their assets (Velez-Ibanez & Greenberg, 1992). Previous studies have identified funds of knowledge that can be utilized for science learning including gardening, cooking, home remedies (Riojas-Cortez, Huerta, Flores, Perez, & Clark, 2008), parents' occupations, travel from other places, environmental problems, health problems, experience working on cars, wearing bike helmets (Moje, et al., 2004), hunting experiences, and local fossils (Borgerding, 2017).

Funds of knowledge can serve as resources in educational contexts (Moll, Amanti, Neff, & Gonzalez, 1992) and necessitate a type of relevant instruction “linked to local histories and community contexts” (Gonzalez & Moll, 2002, p. 623). In a classroom employing funds of knowledge approaches, teachers and learners create a “third space” wherein these funds of knowledge can be integrated in new ways (Moje, et al., 2004). Some of the teaching methods advocated by these funds of knowledge researchers include soliciting students’ out of school examples (Tan & Barton, 2010), sharing teachers’ own personal life examples (Upadhyay, 2006), actively inviting parents into classrooms (Tan & Barton, 2010), and using analogies, examples, and questions (Irish & Kang, 2018). Teachers can use students’ funds of knowledge to provide a “hook” for promoting student interest, help students find deeper meaning in science learning, and position students as experts with respect to science knowledge (McLaughlin & Barton, 2013).

When science instruction harnesses students’ funds of knowledge as assets, several positive outcomes result. These include improving learning outcomes (Barton & Tan, 2009) and increasing interest and participation (Cowie, Jones, & Otrel-Cass, 2011; Rohandi & Md Zain, 2011). When these funds of knowledge are coupled with authentic science inquiry projects, researchers have also noted gains such as a greater sense of academic agency, opportunities to gain expertise, and increased identification with science (Rivera Maulucci, Brown, Grey, & Sullivan, 2014). The supportive environment that values students’ funds of knowledge has even improved in- and out-of-class behaviors and improved student and teacher relationships (Rohandi & Md Zain, 2011). Finally, the opportunity for often-marginalized students to become experts and share their experiences with other class members can increase student self-efficacy and pride in their culture (Stevens, Andrade, & Page, 2016). Thus, by tapping into students’ funds of knowledge, instructors can both improve content understand and empower their students as learners.

In this study, we conceptualize college students’ experiences with American football as potential funds of knowledge for learning about physical science content. Some college science learners have a wealth of football playing and viewing experience, and skillful funds of knowledge instruction may be able to harness these experiences to make science learning more powerful and relevant. By identifying the range of football experiences and connections students make between those experiences and physical science content as this study attempts to do, science educators may plan instruction that is more meaningful to learners.

Science, Sports, Physics, and Football

Engagement in sports is a common everyday experience for many U.S. children and adolescents. Students’ experiences with movement, muscles, injuries, and sports projectiles may all serve as funds of knowledge for science learning. Several science education practitioner journals provide background information to help science teachers connect their science teaching to common sports. Some examples address friction in ice hockey (Hache, 2008), the use of technology to enhance sports performance in soccer, pole vaulting, and tennis (James, 2008), and the physics of snowboarding (Swinson, 1994). These practitioner journals provide lessons in which students use chemical reactions to make cold packs for sports injuries (Silberman, 2004), play basketball to learn about measurement and vectors (Bergman, 2010), and use sprinting, javelin-throwing, and high jumping to learn about structure and function (Wegner, Gröber, Berning, & Tönnesmann, 2017).

Empirical research publications investigating the utility and impacts of these science-in-sports approaches are rarer but do exist. The Sisters in Sports Science program was an extracurricular program designed to bridge the academic and everyday experiences of urban girls. Students engaged in basketball, volleyball, soccer, hockey, softball, fencing, golf, tennis, and track to learn about motion, force, aerodynamics, energy transformation, geometry, biomechanics, and simple machines. Participants showed pre to post gains on local content assessments and school achievement. The strong program retention rate and qualitative data indicated participants' satisfaction and enjoyment of the program (Hammrich, Fadigan, Green, Richardson, & Livingston, 2003). Taking a socioscientific approach, Stolz, Witteck, Marks, and Eilks, (2013) used the issue of doping in sports to teach chemistry and motivate student engagement. The results indicated that students were motivated & interested, liked making connections between science and everyday lives. Thus, the findings from these studies suggest that sport contexts can promote student engagement and reveal content understanding of science.

In the study most similar to the present one, Brown and Kloser (2009) investigated 15 high school baseball players' understandings of the physics of baseball's curveball over 2 years. The authors found no improvement on a quantitative test about physics content, but qualitative analysis revealed that the students could explain much of the motion by using every day and baseball language. The students did not often use science language and sometimes used it incorrectly. However, the students used every day and baseball language to correctly explain the difference between speed and velocity, air pressure, changes in velocity, force, and spin. By exploring the physics knowledge of those who engage in baseball, these authors began to identify the sports experiences and vernacular that could be harnessed in science lessons. The present study extends this exploration to the potential of American football to serve as such a science learning context. To our knowledge, no empirical studies have directly explored the students' American football experiences as potential funds of knowledge for learning science as the present study attempts.

The play of American football offers many connections to force and motion concepts. The prolate spheroid shape of the ball was designed to make it easy to carry and to optimize its aerodynamics and to reduce air resistance for passing (St. John & Ramirez, 2013). The throwing and kicking of the football illustrates many aspects of projectile motion. Furthermore, when football players pursue each other defensively, several aspects of linear motion are manifested. Finally, football inflation and deflation and their impact for play can be explained by air pressure and gas laws (Megonigal, 2015).

American football is a very popular sport within the U.S. In fact, football has been the favorite spectator sport among Americans since 1972 with 37% of American adults citing it as their favorite sport to watch in the most recent Gallup poll (Norman, 2018). Furthermore, college football in particular is the most dominant and commercialized collegiate sport (Thelin, 2011). Teachers and curriculum developers have sought to harness the popularity of this sport. The appeal of American football has even prompted its use as a context for teaching discrete math (Muldoon Brown, 2015) and French language (Berwald, 1974).

In particular, science education's practitioner journals are replete with lessons that use football examples and contexts for teaching about physical science concepts. Several examples include using the Super Bowl's notorious "Deflate-gate" to teach about pressure/temperature relationships (Blumenthal, et al.,2016; Megonigal, 2015), kicking a football to teach about projectile motion and aerodynamics (Brancazio, 1985), football evasion tactics to teach about graphical relationships and experimentation (O'Connell, 1995), and video clips of athletes to teach about motion and scientific modeling (Zollman, Noble, & Curtin, 1987). Famously, a University of Nebraska physics professor used his college's outstandingly-attended and viewed football games as an opportunity to teach the physics of football (Hartill, 2000).

Inherent to all of this curricular work is the assumption that football is a relevant context in which physics teachers can build upon student interest and experiences for teaching physical science concepts. Yet, the extent to which these football contexts elicit physical science concepts from learners has not been empirically investigated. This study attempts to fill this research gap.

Purpose

This purpose of this research study was to explore how American football scenarios elicit physical science concepts in relation to the personal experiences of college undergraduates. These personal experiences with football represent funds of knowledge for physics. Our project is guided by the overall research question, "What kinds of funds of knowledge do students have from their sports experiences to help them learn about physical science motion and force concepts?" These funds of knowledge can potentially be built upon for future science instruction. Thus, this overall research question necessitates an exploration of the ways in which American football contexts elicit physical science concepts, relevant personal experiences, science misconceptions, and correctly and incorrectly-used scientific vocabulary. The guiding research questions were:

(1) What are the physical science concepts elicited from football contexts?
(2) Which football contexts elicited particular science concepts?
(3) What participant football experiences afforded knowledge about physical science concepts associated with football?

Methods

Because this project was exploratory in nature, we employed a qualitative, interpretivist approach in order to understand a wide range of college science learners' perspectives on the science concepts associated with American football. Specifically, we utilized individual interviews and one focus group as data sources for these perspectives.

Ultimately, the authors sought to identify funds of knowledge learners bring to college science learning. In discussion about underrepresented groups in science, the authors chose physical science content connected to football experiences because this subject is often deemed challenging while the football context is quite popular. This topic also matched the local experience within our research team. The research team consisted of five individuals with different relationships to both American football, physics, and science teaching. The first four authors are all former secondary science teachers, and the fifth author is a collegiate football coach and former physical education teacher. The first author also led physical science professional development courses for middle school teachers for several years. This research team brought these different perspectives to the research design, data collection, and data analyses approaches.

Sample

Our general approach to sampling was to include college science learning participants who are familiar and unfamiliar with football to identify a wide range of experiences related to football including those who play football, regularly attend football games, casually watch football on television, and have less familiarity with football. Additionally, we sought a sample that had a diversity of experiences with formal physical science content. Because of our affiliation with the College of Education at our institution, we primarily targeted a convenience sample of secondary teacher education students from several content majors: preservice social studies teachers who are likely least familiar with formal science content, preservice science teachers who are likely familiar with formal physical science content, and preservice physical education teachers who are likely familiar with both sport and anatomy/physiology content knowledge. We also included a college football player at our institution because of his expertise in mechanics of the play of football. In total, our sample consisted of 22 college students: 13 preservice social studies teachers, seven preservice science teachers, one preservice physical education teacher, and one college football player majoring in Sports Administration. With this sample, we sought to explore a variety of college students' football experiences and the ways these college students made connections between these experiences and physical science content.

Data Collection

Individual interviews and a focus group were used as the data sources for this project. The research team developed the protocols by starting with common football actions (passing, kicking, and tackling) and identifying possible physical science content evident in these scenarios. Initial probing questions were written, and the research team mock-interviewed each other to identify possible follow-up probes, points of clarification, and improved wording. The final protocol included football scenario questions that targeted different aspects of force and motion: why a football is shaped the way it is, what needs to be done to throw a football the farthest, the angle at which one kicks a football, the impact of wind when kicking a football, pursuit angle for defenders, and football deflation. The complete interview protocol is included in the Appendix.

The data collection consisted of individual interviews that lasted 10-20 minutes and were audiotaped. Participants were also asked to provide information about themselves, including the sports they play or watch, interest in science, and coursework in science. Because a large group of social studies preservice teachers were available at the same time, nine of them participated in an audiotaped focus group during which time each participant was individually asked each question with relatively limited follow-up questions. Table 1 outlines the sample according to their major, self-professed interest in science and football-playing experience.

Table 1. Study Participants

Major	*Number of Participants*	*Percentage with Interest in Science*	*Percentage with Football-Playing Experience*

Secondary Social Studies Education	13*	38.5%	38.5%
Secondary Science Education	7	100%	57.1%
Secondary Physical Education	1	100%	100%
Sports Administration	1	0%	100%

*Nine of these 13 participated provided their responses in a focus group

Data Analysis

The qualitative data analysis of the interview transcripts was guided by a constant comparative method approach as described by Glaser and Strauss (1967). First, a set of three transcripts were open-coded independently by four of the authors. Detailed code notes were taken throughout this open coding process, and the codes were organized by football context (football shape, throwing, kicking, kicking into the wind, tackling, and ball deflation. The authors met to discuss the general classes of codes being generated, deciding to collapse some codes and noting general trends, resulting a set of Round 1 consensus codes. Three of the five authors then took these Round 1 consensus codes and applied them independently to another set of five (including the original three transcripts). The authors met, discussed the codes, and added the new codes to the Round 1 consensus codes, generating the Round 2 consensus codes. This Round 2 consensus coding scheme was then independently applied to 12 more transcripts. Again, the authors met, discussed codes, and consolidated codes into the Round 3 consensus codes. These three authors independently applied the Round 3 consensus codes to the remaining five transcripts, met to discuss the coding, collapsing and organizing codes into the Final Consensus Codes.

These Final Consensus codes were then sorted according to Science Concept (a property of the codes themselves), Football Context (a property of the interview scenarios) and also by Participant Football Experience (a characteristic of individual participants). These disaggregated data sets were then analyzed to generate trends regarding the football contexts that elicited particular science concepts and the role of football experience for eliciting particular science concepts. Tables elucidating these codes and their exemplars, data disaggregated by context, and data disaggregated by football experience are presented in the results section.

Results

We present findings from the interviews organized by three themes: (1) the physical science concepts elicited from football contexts, (2) the football contexts that elicited particular science concepts, and (3) participant football experiences that afforded knowledge about physical science concepts associated with football.

Physical Science Concepts

Participants frequently discussed physical science topics in the context of football. Table 2 shows the different physical science concepts that emerged when participants were discussing the different football contexts. In particular, the following physical science concepts were most frequently mentioned: Linear motion (speed, velocity, and displacement), force, gravity and weight, projectile motion (velocity vectors, acceleration, time, position, and angle), Newton’s Second Law, air pressure, air resistance, momentum, power, torque/rotational motion, and thermal expansion/gas laws.

Table 2. Science Concepts and Exemplars Elicited by Football Interviews

Physical Science Concept	*Participant Exemplar*
Linear Motion: Speed, Velocity, & Displacement	"your angle because like you're going to be a little, because if someone is going straight forward and you try to run straight at them…unless you're way faster than them, you're not going to get up to them" (Kedrick, Social Studies)
Force	"[at] the twenty-five you're not going to put as much force behind it as you would kicking from the forty yard line." (Robin, Science)
Gravity and Weight	"And then you also want to give it a little bit of an arc so the gravity doesn't pull it straight into the ground." (Tim, Science)
Projectile Motion: Velocity vectors, Acceleration, Time, Position, Angle)	"if you're further away you've got to keep it low so that it can travel further, because if it goes too high it won't go as far." (Ned, Social Studies)
Newton's Second Law	"the force times mass equals acceleration" [incorrect] (Sam, Football)
Air Pressure	"Sometimes air pressure, like when you throw a football sometimes…you've got to figure footballs get cut and tackled so many times" (Jordan, Social Studies)
Air Resistance	"I think that they wouldn't be able to throw it as far because of air resistance and surface area, so I think that it's shaped like that because of the wind and it allows it, the way that it's shaped allows it to travel farther" (Mia, Science)
Momentum	"whether it's for a touchdown pat or a 60 yard field goal, you kinda want to keep the same mechanics and momentum." (Sam, Football)
(Angular Momentum) Spiral Motion	"so it'll travel better, a streamline spiral" (Ken, P.E.)
Power	"[if you] Kick it lower, more power" (Ian, Social Studies)
Torque/Rotational Motion	"so you got you know your torso's twisting back your arms coming back behind your head, shifting your weight, so shift your weight forward step in with opposition with your other leg." (Ken, P.E.)
Thermal Expansion/Gas Laws	"If it was colder it would lose air pressure." (Chris, Science)

When explaining the football scenarios, participants correctly used many terms. Participants often used the terms "velocity," "force," "gravity," air pressure," "air resistance", "PSI," "momentum," and "torque" correctly. For example, Rob (football) correctly connected the concept of velocity (speed) as influencing momentum when he described how to make a tackle by having "more momentum because…you're going to drive them back, you're going faster." Similarly, Sam (football) correctly used the term "torque" when explaining how to kick a football, "that's where you get more power and you can obviously get more power when your pulling it 'cause you have the torque in your hips." In many cases, participants correctly used the science terminology.

Often, participants described physical science concepts without using science terms directly. For example, Jordan clearly captured the meaning of "velocity" when he explained his thinking during a tackling scenario, "How can I get around him and like one or two steps to get to the quarterback quicker than a three or four steps to try to? It's all about speed and angles."

Similarly, Ken did not use "velocity" but explained his approach to tackling as "I'd have to take an angle that I could get to him the earliest." Sam (football) did not directly state "air resistance," but this meaning is implied when he explained the shape of the football with, "I would assume it's for the way you throw the ball potentially cut through the wind." Ned (football) used football terms "pursuit angle" but was really connecting several linear motion ideas such as relative velocity and vectors when he described a tackling scenario, "you'd take a pursuit angle so like you're trying to see where they're going and you're going to. You don't run right at them you're going to…try to kind of make like a triangle…to meet them at a certain spot." Kedrick (football) connected several linear motion ideas too in his description of a tackling scenario: "if you know that someone's like a lot faster than you, you'll probably want to take more of a steeper angle." Similarly, Kedrick used projectile motion concepts without explicitly mentioning launch angle: "And if you kick it at forty you're going to want to get a little more distance so you might want to kick it a little more shallow." Finally, Ken (football) did not directly say "torque" but he clearly understood how it is generated in a kicking context: "your torso's twisting back your arms coming back behind your head, shifting your weight, so shift your weight forward step in with opposition with your other leg."

Some participants revealed partial understandings of concepts. For example, many participants demonstrated a partial understanding of thermal expansion of gases, but they did not use these terms. For example, Jordan (football) connected air pressure and snow, without directly connecting air pressure with temperature. He explained ball deflation as related to "the air pressure in it, like snow that's going to cause a football deflate a little bit it's not going to deflate like it would like flat."

Occasionally, participants used science terms incorrectly. Sometimes, participants were confused about a particular term. For example, Sam (football) was clearly referencing Newton's second law when he incorrectly stated "the force times mass equals acceleration." Also, Jordan (football) did not seem to understand "velocity" when he explained how to throw a football the farthest by "it depends on how strong I guess your arm is like. It's all science involved in it. Your arm velocity has to be pretty short."

In other instances, participants revealed confusion about physical science concepts. Across several interviews, there was confusion about football deflation in terms of mass/weight. For example, Mandy (science) said, "if it's deflated I think that, for some reason I'm thinking that the ball will be heavier a little bit heavier because there's less air in it." Ned (football), on the other hand, said, "I guess the weight would be less" and Ken said, "it probably weighs a little bit less." Similarly, Rob indicated that the ball **"**wouldn't have as much mass so it would be more impacted by wind**."** Thus, for several participants, there was confusion about how deflation might impact weight and buoyancy in the air.

Participants occasionally connect multiple physical science concepts in a single response. Some participants connected concepts like spiraling (angular momentum) and air resistance. For example, Sam (football) explained, "if you don't throw a spiral you're going to have more stuff cutting through the wind uh affecting the flight of the football where as if you have a tight spiral you keep the rotation and get more distance off of it." Other participants connected air resistance, surface area, and distance travelled. Mia (science) explained how football players "wouldn't be able to throw it as far because of air resistance and surface area, so I think that it's shaped like that because of the wind and it allows it, the way that it's shaped allows it to travel farther." Similarly, Aaron (science) reasoned about kicking using a force-diagram approach, trying to account for the forces on the ball in a windy kicking scenario. He explained, "all the force is going to be coming from how you kick it. The only resistance would be the wind like the air resistance."

Several participants connected specific aspects of geometry as well as science. For example, Devin (science), Chad (science), and Nick (football) all described how "the ideal launch angle…would be forty-five degrees" (Chad, science). Similarly, Sam (football) described his approach to kicking in terms of angles: "So let's say you take your three steps back at the right angle, you take your two steps over at this angle now you have an obtuse angle, and now you are going to be too far away from the ball causing you not to hit it correctly."

Football Contexts

Not surprisingly, particular football contexts elicited particular science concepts. Table 3 lists the particular science concepts that were elicited by the various football contexts. As shown in Table 3, some football contexts elicited many science concepts, and these particularly fruitful contexts included the shape of football, throwing, and deflation.

Table 3. Football Contexts that Elicited Particular Science Concepts

Football Context	*Physical Science Concepts*
Shape of Football	Linear Motion: Speed, Velocity, & Displacement, Projectile Motion, Angular Momentum (Spiral), Air Resistance
Throwing	Gravity, Projectile Motion, Angular Momentum (Spiraling), Torque, Power, Air Resistance, Momentum
Kicking	Projectile Motion, Force, Momentum, Air Resistance, Power, Torque
Kicking into the Wind	Projectile Motion, Linear Motion, Power, Torque, Air Resistance
Tackling	Projectile Motion, Linear Motion, Force, Momentum
Deflation	Air Pressure, Thermal Expansion, Gravity/Weight, Air Resistance, Projectile Motion, Newton's Second Law

Often, participants connected their interview responses back to personal experiences. Three contexts elicited these personal experiences. First, the ball deflation scenario prompted experiences with maintaining equipment in the winter. For example, when Sam (football) was thinking through the deflation issue, he remembered, "Having so many footballs in my life that I have left in my garage over winter and by the time spring comes well now my balls are flat so the weather definitely has an effect on the psi or whatever it is on the balls." Second, the shape of the football as a means to facilitate throwing prompted at least five participants to reflect on their experiences with other types of balls in other sports. For example, Jordan compared the balls of several sports: "if you get too big like a basketball, it's going to be harder throw down a field…you can't use a baseball because baseball is too small. A football is like the right size for like either catching, throwing, running." Devin reasoned through why the football is shaped as it is by comparing the football to a rugby ball: Rugby has a ball that's similar in shape. I would say it's more for aerodynamics." Third, Sam (football) reasoned through the specific angle for turning to make a kick by remembering a strategy he learned in high school football camps: “so I would take my steps, put the tape at the back part of my foot, and then take two steps over and put the tape on the back of my foot” to get the best turn angle.

Occasionally, rather than drawing on their own football experiences, students would illustrate their physical science understandings by mentioning college or professional football players. For example, several participants immediately referenced Tom Brady, the NFL player most closely associated with the 2015 “Deflate-gate” controversy in a championship game. Additionally, Ken illustrated his kicking scenario explanation of “power” by explaining, “like so Justin Tucker, I’m sure he holds back a little bit for accuracy purposes but don’t you think you would be kicking it pretty freaking hard each time?” In a similar way, Sam (football)explained his understanding of “power.” He said, “the power doesn’t come from deadlifts and squatting and doing leg lifts and having strong legs. I mean I’m only 170 pounds and Sebastian Janikowski from the Oakland Raiders is like 240 so I mean it doesn’t matter how strong you are. It matters how consistently you hit the ball and your contact.”

Participant Football Experiences

Given this study’s focus on how participants use their background knowledge and experiences to make sense of physical science questions prompted through different football contexts, we compared how participants with different backgrounds provided the various science concepts. We compared the physical science codes elicited by four groups of students: those with football-only experience, those with science-only experience, those who had both football and science experience, and those who had neither football nor science experience. Table 4 compares the physical science codes elicited by each group. Although we expected that those participants with any science experience would be highly inclined to explain football scenarios in terms of scientific concepts, we found that participants with football experience utilized science concepts very frequently as well.

Table 4. Science Concepts Elicited by Participants with Varying Football and Science Experiences

Physical Science Concept	*Experiences*			
	Football	*Science*	*Football AND Science*	*Neither*
Linear Motion	X	X	X	
Force	X	X	X	
Gravity and Weight	X	X	X	
Projectile Motion:	X	X	X	X
Newton’s Second Law	X			
Air Pressure	X	X	X	
Air Resistance	X	X	X	X
Momentum	X		X	
(Angular Momentum) Spiral Motion	X	X	X	X
Power	X	X	X	
Torque	X	X	X	
Thermal Expansion/Gas Laws	X	X	X	

While Table 4 elucidates which groups of students utilized particular science concepts to explain football scenarios, Table 5 highlights how particular groups of students correctly utilized specific science terms in their responses. Again, we expected that participants with a science background would be inclined to correctly use science terms, and certainly this was the case. But, participants with only football experience also used specific terms frequently. That being said, terminology use varied within each category of experience. For example, two participants used science terms correctly more than ten times: one preservice science teacher who also played football and also the football player.

Table 5. Correct Use of Science Terms (Numbers = Total Utterances)

Term	*Football*	*Science*	*Football AND Science*	*Neither*
Velocity	4		1	
Force	2	1	2	
Gravity	1		1	
Mass	1			
Air Pressure	2		5	1
Air Resistance		1	7	
Psi	2			
Momentum	3		1	
Power	10	1	4	
Torque	1		2	

Discussion and Implications

This study contributes to the field of science education in two main ways: as empirical support for using American football contexts to elicit physical science concepts and as an illustration of a funds of knowledge approach to science teaching and learning in a new context. Both of these contributions are detailed below. We follow these descriptions with some future directions for research and a discussion of the limitations of this study.

Football as a Context for Physical Science Learning

Although football examples have long been recommended in science education practitioner examples, this study provides empirical evidence of their utility. First, the study identified and piloted a range of football contexts to determine the kinds of physical science ideas that would be elicited. Some football scenarios elicited a broad range of physical science concepts (e.g. throwing a football) while others elicited a narrower range of concepts (e.g. tackling). When teaching specific topics, the more narrowly-targeting scenarios could be used in instruction, while the broadly-targeting scenarios could be used as entry anchoring event (Stroupe, 2017) that drives instruction throughout a force and motion unit.

Second, the study identified specific prior experiences that science teachers can integrate into their instruction. These football scenarios elicited both personal experiences such ball deflation in the winter or vicarious experiences watching football that can be used to make physical science teaching more relevant. Irish and Kang (2018) recommend funds of knowledge instruction in which lessons are grounded in contexts familiar to students and open enough that they can engage in science and engineering practices. In this regard, instructors can build a projectile motion unit around the kicking scenario and challenge the students to draw upon their football knowledge to predict or explain the physics of football motion.

Third, the football scenarios were useful for drawing out students' science misconceptions and areas of confusion. As participants reasoned through the scenarios, they sometimes became aware of the limits of their physical science understandings, a necessary condition for conceptual change instruction (Posner, Strike, Hewson, & Gertzog, 1982). A teacher using these contexts could use these examples as formative assessment probes to identify common areas of confusion or to make students aware of their misconceptions.

Fourth, this study illustrates how these experience-rich scenarios give students an opportunity to use and appropriate the language of science (Lemke, 1990). When presented with a scenario, both the science-experienced as well as the football-experienced participants used the academic language of physical science. Previous research has shown that some physical science terms like "momentum" have very similar meanings in everyday (sports and politics) and scientific contexts (Haglund, Jeppsson & Ahrenberg, 2015). Science instruction can take advantage of these parallels between sport and scientific usage of terms. As illustrated within our data, several participants described physical science phenomena without directly using the physical science academic vocabulary, findings similar to Brown & Kloser (2009). From an instructor's point of view, these students are ready to add terminology to these experiences as part of a learning cycle (Karplus & Their, 1969) approach. As such, Brown and Ryoo (2008) determined that students taught science concepts using everyday language first showed greater learning gains than those taught using scientific language first.

Funds of Knowledge Approaches for Science Teaching

This study also adds to the growing literature on funds of knowledge as a means by of making science instruction more culturally relevant for learners. First, this study helps by illustrating the need for understanding student experiences (Tan & Barton, 2010). When given the opportunity, participants readily offered many life experiences that dealt directly with science content. Once discovered, a skilled teacher could use these opportunities as "hooks" for engagement in science instruction (McLaughlin & Barton, 2013). In this football context, students' experiences with deflated footballs in winter, attempts to make a tackle, and throwing different kinds of balls lend themselves to physical science instruction. In one recent study of classrooms attempting to harness students' funds of knowledge, students admitted that even when prompted, they do not often think of their out-of-school experiences as relevant to science lessons (Irish & Kang, 2018). An awareness of the many possibilities for using American football examples to teach physical science may help teacher more directly prompt students to make these connections.

Second, this work serves as an attempt to answer Tan and Barton's (2010) call to connect science instruction with students' out-of-school experiences. Interestingly, the football scenarios conjured participants' own experiences with football as well as their vicarious experiences watching football live or on television. Vicarious experiences for science learning may offer an even broader range of opportunities to connect to science learners, and these funds of knowledge must be further investigated. By connecting science instruction to highly-watched televised sporting events like the Olympics, soccer's World Cup, biking's Tour de France, teachers may be able to capitalize on these vicarious experiences.

Third, the football scenarios positioned many participants as experts (McLaughlin & Barton, 2013) when discussing physical science concepts. This study demonstrated that those participants with science-only experience, science and football experience, and football-only experience offered the most science concepts and utilized the science vocabulary. In this way, these culturally-relevant examples have the promise to broaden participation in science learning and science talk. If a class were to engage in an inquiry involving the use of a deflated football, students who do not regularly identify with the culture of science may take on leadership roles as their peers use their local expertise to make sense of a scenario. This leadership and expertise for teaching others may improve self-efficacy and pride (Rohandi & Md Zain, 2011).

Study Limitations and Suggestions for Further Research

A few key limitations of this study must be considered in order to contextualize the findings and identify fruitful areas of further research. The first set of limitations of this study center around its sample. The sample primarily included preservice secondary teachers (science, social studies, and physical education). These preservice teachers may be unlike other undergraduates in that they already see the value of connecting everyday experiences to more traditional school content. In this way, they may have been more forthcoming about possible relevant everyday experiences. Additionally, because the sample was not random, statistical comparisons of subgroups (such as those with science-only, science and football, and football-only expertise) could not be made. A future study could use a larger, random sample of undergraduates in order to make statistical comparisons of these subgroups.

A second limitation is that this study was exploratory in nature because few previous studies of its kind had been conducted. As such, the study employed a qualitative research design well-equipped for rich characterization of phenomena within this particular context. Thus, the findings may not be generalizable to other universities or even different majors within this university. Using the findings of this study as a foundation, future quantitative research could be designed in order to permit such generalizability.

An additional limitation of this study was that it did not include measures of participants' understandings of force and motion concepts and even football itself. The interviews captured participants' perceptions of their own expertise in football and physical science and occasionally revealed confusion or misconceptions about the latter. Future studies could more systematically assess participants' knowledge of force and motion concepts and knowledge of football itself.

Finally, because the purpose of this investigation was to examine the funds of knowledge students can bring from their sports experiences to help them learn about physical science motion and force concepts, no specific intervention was employed. Given the findings of the promise of connecting force and motion instruction to these funds of knowledge, specific interventions and associated curricula could be developed to embed common sport experiences (e.g. football or gymnastics). These curricular interventions could then be tested regarding the extent to which they actually serve as a hook for learning (McLaughlin & Barton, 2013), elicit student ideas about the science, and impact science content learning.

Conclusions

This exploratory study provides empirical support for the utility of American football scenarios as useful contexts for culturally-relevant physical science instruction. When prompted by football scenarios, participants shared relevant personal and vicarious experiences, attempted to apply their knowledge of physical science concepts, revealed areas of confusion and misconceptions, and engaged with the language of physical science. This study also offers another concrete example of how funds of knowledge approaches can be used in science teaching and research. For students with science-only, science and football, and football-only experience, the football scenarios served as a rich context to engage with physical science. These findings provide support culturally-relevant instruction as way to broaden participation in science learning.

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Appendix

Interview Protocol
General

1. What is your major?
2. What year in school are you?
3. What sports do you play?
4. How familiar are you with football?
5. Have you ever played football yourself?
6. How frequently do you watch football on TV?
7. How interested are you in science?
8. What science classes did you take in high school and in college?

Shape of the Ball

9. Why do you think a football is shaped the way it is? (Why does it have points? What does it help people do?)

Throwing

10. What would you have to do to throw a football the farthest? (probe for: how would you hold it? How high would you throw it? Would you spiral it or not?)

Kicking

11. If you were kicking the ball to try to go through the goalposts, how would you know how to kick the ball in order to score?
    a. What would you do differently if you were kicking from the 25-yard line instead of the 40-yard line?

Wind

12. Let's imagine you are kicking a field goal at the 30-yard line to get a field goal. What would you do differently if you were kicking:
    a. And there was no wind?
    b. Into the wind?
    c. With the wind behind you?
    d. With a cross wind from left to right?

Pursuit Angle

13. If you ae a defender and you want to make a tackle, what do you have to think about to make the tackle with the least amount of yards given up? (probe for speed/angle)

Inflation

14. What causes a football to deflate?
15. Would you rather throw an over- or under-deflated ball? Why?
16. How would deflation affect the accuracy of the pass?