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Students' perceptions of vocabulary knowledge and learning in a middle school science classroom

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ABSTRACT
This study investigated eighth-grade science students' (13–14-year-olds) perceptions of their vocabulary knowledge, learning, and content achievement. Data sources included pre- and posttest of students' perceptions of vocabulary knowledge, students' perceptions of vocabulary and reading strategies surveys, and a content achievement test. Students' perceptions of vocabulary knowledge were compared before and after instruction to see whether students believed they gained knowledge and the ability to explain categories of technical science terms. Students' perceptions of vocabulary knowledge increased as a result of instruction. The participants had favorable views of the vocabulary and reading strategies implemented and believed the literacy approaches were important for their developing science knowledge. In addition, students' content achievement was compared to a national data set. Students in this study outperformed a national data set on all content knowledge items assessed. Students' perceptions of their knowledge and vocabulary and reading strategies were congruent with their content achievement. This study is one of the first to highlight the pivotal role students' perception of vocabulary knowledge and vocabulary and reading strategies plays in science content learning.

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Literacy strategies; vocabulary learning; metacognition

Calls for widespread educational reforms in the USA come from evidence indicating students are not adequately prepared for college, the work force, and a technological advanced twenty-first century society (International Society for Technology in Education [ISTE], 2007; National Center for Educational Statistics, 2003; Partnership for 21st Century Skills, 2002). In the USA, experts in education agree that reforms in education must promote a set of interdisciplinary, cross-cutting initiatives called Common Core State Standards (CCSS) to help develop students' higher levels of thinking (National Governors Association Center for Best Practices [NGA] & Council of Chief State School Officers [CCSSO], 2010). The CCSS highlight that instruction should promote students gathering, comprehending, assessing, and synthesizing information presented in technical texts. In order for students to begin to meet these standards, they must be able to read, comprehend, and make sense of complicated vocabulary and text passages. While developing students' abilities to learn from reading is an important goal, science can be

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extremely difficult for learners because of technical terminologies (Groves, 1995; Yager, 1983). The purpose of this study is to investigate middle school science students' perceptions of vocabulary knowledge, vocabulary learning, and science content learning.

Research questions

This study focuses on research questions aimed at investigating whether shifts occur in students' perceptions and knowledge before and after implementation of literacy strategies. The research questions include:

(1) What are the differences in students' perceptions of specific science vocabulary after learning science using literacy strategies?
(2) What are students' perceptions of instructional strategies designed to learn formal science vocabulary?
(3) How do students' content achievement compare to a national data set?
(4) What is the relationship among students' perceptions of vocabulary knowledge, perceptions of instructional strategies, and content knowledge achievement?

Theoretical framework: constructing vocabulary knowledge from reading

Vocabulary learning is an active cognitive process where students construct understanding based on new and prior knowledge, personal and social experiences, and the content they are learning (Snow, Griffin, & Burns, 2005; Vygotsky, 1986). Constructing vocabulary knowledge is based on the premise that learners construct new ideas based on existing knowledge (Bruner, 1990). For example, knowing the meaning of words does not necessarily mean a learner will understand what they read; rather, knowing the meaning of words is an indication of a learner's prior knowledge and experience with the content (Nagy, 2005). Thus, constructing vocabulary knowledge from reading is complex because leaners need to understand words in relation to their prior knowledge and the situation presented in the text (Kamil & Hiebert, 2005). Gee (2000) noted that how students construct knowledge from reading is a result of the structure of the text, student's prior knowledge, and student's experiences in learning new content (e.g. sociocultural context). Consequently, students' development of science literacy from reading is heavily dependent on the expertise of the reader, in terms of both their science content knowledge and overall literacy, and the setting in which learning occurs.

A critical component of constructing vocabulary knowledge is a student's ability to actively monitor their understanding while reading. Students must recognize (use metacognitive strategies) when they lack understanding and choose strategies to help them develop deeper conceptual understanding. Flavell (1979) argued that metacognitive strategies include knowledge of self, knowledge of aspects of the task, and knowledge of the strategies to master the objective. Knowledge of the self, task, and strategies (also referred to as self-estimates, self-understanding, perceptions of knowledge, estimates of performance) require students to reflect on their current and ongoing understanding to develop higher levels of expertise (Dunlosky & Metcalfe, 2009). Student's assessments of their knowledge can be important indicators of achievement. Research shows that students have reasonably accurate assessments of their knowledge (self-estimate, self-understanding, etc.) and levels of achievement (Kuncel, Crede, & Thomas, 2005).

In science education, vocabulary is essential to discipline-specific learning (Fisher & Blachowicz, 2013). Constructing vocabulary knowledge and reflecting on developing understanding is important because many scientific concepts are abstract or inaccessible (e.g. subatomic particles that comprise an atom, the process of photosynthesis, etc.*) (Carlsen, 2007). Similarly, students cannot explore inaccessible concepts from hands-on experiences. The conceptual framework emerges from the theoretical framework that shows reading instruction is critical in supporting student's content knowledge development and the overall academic achievement (Marzano, Pickering, & Pollock, 2001).

Conceptual framework: close analytical reading

Vocabulary knowledge and reading are inextricably linked (National Institute of Child Health and Human Development, 2000). One of the most clearly defined lines in the research in literacy education shows that students who read widely have expansive vocabularies (Blachowicz & Fisher, 2004). Close, analytical reading (also termed 'close reading') requires students to align new knowledge with preexisting conceptions and attend to the relationship between ideas. Close analytical readings are active experiences that engage students, focus learning on measurable outcomes, and unveil students' prior knowledge and experiences. In this way, close readings draw on research on how students learn science best and focus on students evaluating their knowledge and learning (metacognition), frequent assessment, and a classroom culture that values constructing knowledge (Bransford, Brown, & Cocking, 2000).

A close reading is a scaffold activity where students interact with the text individually, with their peers, and with the teacher to develop deeper understanding. Close reading is a way to read to help students acheive deep comprehension. Scholarship indicates 'close, analytical reading stresses engaging with text of sufficient complexity directly and examining meaning thoroughly and methodically, encouraging students to read and reread deliberately' (Partnership for Assessment of Readiness for College and Careers [PARCC], 2011, p. 7). Studies show that close reading complex texts leads to significant gains in both struggling and advanced readers reading proficiency (PARCC, 2011).

Using strategies to help students explain difficult terms while reading helps novices develop greater conceptual understanding (Reutzel & Cooter, 1996). Integrated vocabulary strategies that explicitly help students describe new ideas (e.g. Anderson & Nagy, 1991) ask students to use new terms and concepts in many contexts (Beck, McKeown, & Kucan, 2002), require students to have multiple exposures to new ideas (e.g. Stahl, 2005), and can productively add to a learner's knowledge. In summary, close reading strategies provide students an explicit focus on constructing new information into thinking structures that promote deeper conceptual understanding.

Significance of study: literacy instruction and science learning

Implementing literacy strategies in science education is important for students to gain higher levels of science literacy (Yore, Bisanz, & Hand, 2003). Of the many definitions of science literacy, Millar and Osborne (1998) described science literacy as one's ability to adequately read, understand, and respond critically to newspaper articles and scientific reports. In this light, science literacy hinges on students' ability to read and comprehend science content by what Norris and Phillips (2003) describe as the 'fundamental sense of scientific literacy' (p. 224). Students must be proficient in reading, writing, and application of science before they can think scientifically or make informed judgments about socio-scientific issues (Norris & Phillips, 2003; Yore & Tregust, 2006; Yore et al., 2003). In addition, students' ability to argue using formal science vocabulary aligns with what is required in science occupations (Phillips & Norris, 2009; Suppe, 1998; Tenopir & King, 2004). As a result, fundamental science literacy and science understanding are closely related and 'improved fundamental literacy leads to enhanced understating of science and improved understanding leads to enhanced fundamental literacy' (Jaggar & Yore, 2012, p. 562).

Some studies investigate student vocabulary learning and text complexity. For instance, Groves (1995) built on Yeager's (1983) work and preformed an analysis of secondary textbooks. His findings reiterate Yeager's study that found a heavy emphasis on formal science terminology. Groves argued that in order to learn formal science terminology, many students resort to rote memorization instead of developing deep conceptual understanding. Other studies show that science textbooks act as a barrier to students' progression toward science literacy. Students understandings of science from science texts is inhibited by readers' personal interpretation of the text (Norris & Phillips, 2003), the lack of understanding among the texture and structure of the text (Meyers, 1991; Norris & Phillips, 1994), comprehension of the text (Pressley & Wharton-McDonald, 1997), and that science is presented to the reader as a litany of truths lacking an argumentative perspective (Ford, 2005; Meyers, 1992; Penney, Norris, Phillips, & Clark, 2003).

While research shows vocabulary can be challenging, an explicit focus on new terminology using vocabulary strategies helps students learn. In a study of 140 elementary students, Guthrie et al. (1996) investigated student's engagement and learning during an interdisciplinary language arts and science lesson. The researchers found after one week the readers gained comprehension and the ability to transfer ideas between new and old conceptions. In addition, the students developed new ways for representing text and abilities to scan multiple texts. In another study of elementary students, Gregg and Sekeres (2006) examined inner-city third graders' vocabulary acquisition from a geography unit that used hands-on materials. During student discussions, they sorted objects to learn targeted vocabulary words in the correct context. In this process, student engagement was pivotal for acquiring and using targeted vocabulary. Yates, Cuthrell, and Rose (2011) examined the use of 'word walls' at the middle school level. Word walls, as described by Yates et al., 'are collections of words that are developmentally appropriate … and words selected for specific instructional purposes' (p. 31). The researchers reported that the word walls were 'cumulative' and provided a 'conversational scaffold' (p. 31). After implementing word walls for the school year, there was a significant increase in the percentage of eighth-grade students scoring at the proficient level in science.

What each of these studies shows is that explicit vocabulary instruction improves student comprehension. These studies reinforce the findings from considerable research over the past two decades in literacy education that demonstrates that reading (e.g. Anderson & Nagy, 1991; Beck et al., 2002; Stahl, 2005) and vocabulary instruction (e.g. Anderson & Freebody, 1981; Baumann & Kameenui, 1991; Beck & McKeown, 1986, 1991; Nagy, Anderson, & Herman, 1985) improve student academic achievement. Although studies show that vocabulary instruction enhances student learning and overall comprehension, few studies explore close reading to help students learn science. No study to our knowledge identifies students' perceptions of vocabulary knowledge and content achievement in a middle school science classroom. To address these gaps in the literature, this study focuses on students' perceptions of vocabulary knowledge, students' perceptions of instructional strategies, and content achievement.

Methodology

This research was conducted in an eighth-grade physical science class at a middle school that is part of a large school district in the central United States. The participants, literacy strategies, data collection, and analysis are described below.

Participants

Forty-one ($n = 41$) eighth-grade students agreed to participate in the study that was evenly distributed among males (49%) and females (51%). The eighth-grade classroom was selected because the students were enrolled in the first author's course of study. Data collection occurred during the fourth month of the school year when students began their unit on types of energy and energy transformation. Types of energy and energy transformations are emphasized in the K-12 Science Education Frameworks (National Research Council [NRC], 2011).

Literacy strategies

Multiple literacy strategies were used to help students learn the intended content and develop domain-specific and general academic vocabulary. The literacy strategies were based on professional development, teaching experience, and research literature. The literacy strategies can be divided into two main, interrelated categories aimed at developing students' conceptual understanding: close reading text passages and integrated vocabulary strategies.

To assist students in developing conceptual understanding of 'old formal science terminology', 'relationship terms', and 'other' types of academic vocabulary (see Tables 2–4), multiple close reading strategies were used for excerpts from the students science textbook (Frank et al., 2007). Close reading strategies asked students to complete two or more of the following tasks either individually or as a whole class: read, annotate, highlight, summarize, define, and/or construct models and mathematical relationships and other representations for text.

To help students develop conceptual understanding of 'formal science vocabulary' (see Table 1), integrated organizer/discussions models (here after referred to as integrated models) were implemented vs. definition-only vocabulary-type instructional strategies. For example, integrated models asked students to complete two or more of the following tasks for a science terminology during a close reading: describe new vocabulary in student's own words, compare new terms with expert descriptions, construct illustrations to depict new ideas, and/or provide examples of new ideas. While students completed

Table 1. Students' pre- and post-perceptions of their knowledge and ability to explain new formal science terminology (e.g. students reported 'I know and can explain terminology').

New formal science terminology	Pre	Post
Kinetic energy	10%	100%
Potential energy	10%	100%
Energy transformations	2%	90%
Gravitational potential energy	2%	88%
Elastic potential energy	5%	88%
Electrical energy	19%	98%
Chemical energy	10%	88%
Thermal energy	22%	98%
Law of conservation of energy	10%	80%
Nuclear energy	17%	83%
Electromagnetic energy	38%	93%
Mechanical energy	33%	83%
Fossil fuels	26%	75%
Nuclear reaction	12%	54%
Energy	40%	80%
Nuclear fission	7%	44%
Power	67%	76%

Table 2. Students' pre- and post-perceptions of their knowledge and ability to explain old formal science terminology (e.g. students reported 'I know and can explain terminology').

Old formal science terminology	Pre	Post
Chemical	36%	71%
Coal	48%	78%
Velocity	57%	85%
Natural gas	40%	65%
Particles	38%	59%
Nucleus	62%	83%
Nuclei	43%	63%
Friction	74%	93%
Marshes	52%	70%
Newton	71%	88%
Petroleum	26%	43%
Matter	68%	85%
Swamps	60%	75%
Infrared radiation	64%	78%
Magnetism	38%	51%
Joules	81%	93%
Atoms	40%	51%
Microwaves	79%	90%
Radio waves	76%	85%
Ultraviolet radiation	71%	78%
Plants	86%	93%
Mass	76%	83%
Compounds	26%	32%
Algae	64%	70%
Height	88%	93%
Molecules	44%	49%
Meters	90%	95%
Reactions	62%	66%
Light	86%	90%
Waves	81%	85%
Motion	83%	85%
Speed	86%	85%
Temperature	93%	88%
Cells	74%	83%
X-rays	79%	88%

Table 3. Students' pre- and post-perceptions of their knowledge and ability to explain old relationship terminologies used in science (e.g. students reported 'I know and can explain terminology').

Relationship Terminology	Pre	Post
Transfer	38%	66%
Identical	62%	83%
Quadruple	57%	76%
Reduced	62%	71%
Reversed	50%	51%
Associated	43%	39%

Table 4. Students' pre- and post-perceptions of their knowledge and ability to explain other terminologies used in science (e.g. students reported 'I know and can explain terminology').

Other	Pre	Post
Electrical	40%	76%
Compress	36%	71%
Electricity	60%	93%
Efficient	46%	76%
Unwinds	17%	46%
Readiness	33%	54%
Kinetos	0%	2%

integrated vocabulary strategies, they were explicitly asked to reflect on their knowledge and understanding of the terms and add information that would help them explain new ideas to novices. Integrative vocabulary models were chosen based on more than 30 years of research indicating that explicit vocabulary instruction and associating new words with mental images or models are effective ways to learn vocabulary (Marzano, 2004).

Data collection

Students participated in a pre and posttest perceptions of vocabulary knowledge and learning that were embedded in the lessons and seamless from normal instruction. The pre- and posttests had been used with students as a teaching strategy frequently during the course and prior to the study. Students completed the pretest before the unit of instruction using literacy strategies and the posttest at the end of the unit prior to the content test. The perceptions of vocabulary knowledge questions prompted students thinking about what they already know, and what they will learn and could contribute to students' developing understanding. The perceptions of vocabulary test only assessed students' perceptions of knowledge and did not evaluate the accuracy of students' perceptions or what students learned. Students could choose not to answer or skip any item on the perceptions of vocabulary knowledge and learning test and were a normal part of the course.

Students completed a content knowledge test as a normal part of the course covering disciplinary core ideas identified by the K-12 Science Education Frameworks and evaluated by the American Association for the Advancement of Science (AAAS) project 2061 Assessment website. Although AAAS has assessments for many different topics, only content relevant to the literacy strategies and unit of study was evaluated. The test questions asked students whether they knew and understood topic questions directly related to the following energy content standards:

> 'Motion energy is also called kinetic energy; defined in a given reference frame, it is proportional to the mass of the moving object and grows with the square of its speed.' … Energy stored in fields within a system can also be described as potential energy. For any system where the stored energy depends only on the spatial configuration of the system and not on its history, potential energy is a useful concept (e.g., a massive object above Earth's surface, a compressed or stretched spring). It is defined as a difference in energy compared to some arbitrary reference configuration of a system. For example, lifting an object increases the stored energy in the gravitational field between that object and Earth (gravitational potential energy). (NRC, 2011, p. 121)

The content test did not focus on vocabulary terms and concepts not specifically addressed in the disciplinary core content of the K-12 Science Education Frameworks or AAAS and focused on what we term 'formal science terminology'. Students could skip or not answer questions on the content test; however, they would be penalized for the missing or incorrect answers for their course grade but not related to the research project. To maintain student confidentiality and protect student identity, any identifiers were removed prior to analysis. In addition, all results about students' perceptions and content tests were analyzed for research purposes and reported in aggregate form with all identifiers removed after the completion of the course and final grades submitted.

Data analysis

To report the main findings of the investigation, both descriptive and inferential statistics were used depending on the nature of the research questions. In terms of descriptive statistics, means were calculated to determine the predominance of student responses on the perceptions of vocabulary knowledge and instructional strategies. A three-point response scale was employed to assess students' perceptions of literacy strategies (Agree, Neutral, or Disagree) and perceptions of vocabulary knowledge (both pre- and posttest) (I know and can explain terminology, I know (familiar but cannot explain) terminology, or I don't know terminology). The percentage of student responses on items were calculated. Thus, for the perceptions of literacy strategies survey, the percentages indicate the number of students who reported whether they agreed, were neutral, or disagreed with statements about close reading and vocabulary. Similarly, for the perceptions of vocabulary knowledge tests, the percentages indicate the portions of students who believed they either knew and could explain terms, knew terms (familiar) but could not explain them, or did not know the term.

Inferential statistics were used to determine differences in students' perceptions of knowledge of vocabulary terms. Students' pre- and posttest vocabulary scores were composed of four separate subscales labeled: 'new formal science terminologies', 'old formal science terminology', 'relationship terms', and 'other'. The separate subscales included the terms identified in Tables 1–4 (Tables 1–4 are representative of the pre- and posttest). A Paired Samples *T*-test was performed and Cohen's *d* values calculated to determine if there were significant differences for the mean values for the four subscales for the pre- and posttest.

In terms of the content results, the AAAS Project 2061 website field tested items with a sample population of approximately 1000 middle-level students (AAAS, n.d.). Both inferential (chi-squared test of independence) and descriptive statistics were used to compare the percentage of participants' correct responses with the AAAS Project 2061 national data set ($n = 1000$). The comparisons between the test population and national data set lend insight to whether the literacy strategies promote content achievement.

Findings

The results of this study are divided into four sections related to the research questions. The first section displays results for the pre- and posttests of students' perceptions of vocabulary knowledge that occurred during the time the literacy strategies were implemented. The second section displays student's perceptions of vocabulary and close reading strategies used to learn science content. The third section reports student achievement on the content test compared to a national data set. The fourth section draws comparisons among students' perceptions of vocabulary knowledge, perceptions of instructional strategies, and content knowledge achievement.

Students' perception of vocabulary knowledge

As shown in Tables 1–5, there were differences in students' pre- and post-perceptions of their knowledge and ability to explain new formal science terminologies (see Table 1), old formal science terminology (see Table 2), relationship terms (see Table 3), and other terms (see Table 4). The percentages shown in Tables 1–4 indicate the proportion of students who marked 'I know and can explain terminology' on the pre- and posttest. Each table is arranged from the greatest shift in students' perception of knowledge for a specific term to the least shift in their perceptions of a specific term.

There were differences in student's perceptions of vocabulary knowledge of new formal science terminology for every term assessed (see Table 1). The most notable shifts in student's perceptions of vocabulary knowledge were for the terms 'kinetic energy' and 'potential energy' (from 10% to 100% after instruction). Students' perception of their knowledge of the term 'power' changed the least from 67% to 76% from pre- to post-instruction.

As shown in Table 2, there were differences in students' perceptions of vocabulary knowledge for all terms evaluated. Students' beliefs about their knowledge of the term 'chemical' changed the most from pre- to posttest (from 36% to 71%). For the terms 'speed' and 'temperature', students reported higher perceptions of vocabulary knowledge before than after instruction (86% vs. 85% and 93% vs. 88%, respectively).

Table 5. Student's pre- and post-perceptions of their knowledge and ability to explain categories of science terminologies.

Categories of terminologies	Pre	Post	Paired samples *T*-test, Cohen's effect size
New formal	(M= 1.79, SD = 0.41)	(M = 2.75, SD = 0.26)	$t(39)= 17.56$, $p < .01$, $d = 2.78$
Old formal	(M= 2.58, SD= 0.31)	(M= 2.73, SD= 0.27)	$t(39)= 4.74$, $p < .01$, $d = 0.75$
Relationship	(M= 2.34, SD= .51)	(M= 2.56, SD= 0.42)	$t(39)= 3.73$, $p < .01$, $d = 0.59$
Other	(M= 2.09, SD= 0.39)	(M= 2.45, SD = 0.38)	$t(39)= 5.48$, $p < .01$, $d = 0.87$

Students' perceptions of their knowledge changed for relationship terms used in science (see Table 3). Students' perceptions of their knowledge of the term 'transfer' increased from 38% before instruction to 66% after instruction. Students' beliefs about their knowledge of the term 'associated' decreased from 43% before instruction to 39% after instruction.

As shown in Table 4, students' perceptions of their knowledge of 'other' terms used in science changed from pre- to posttest. Students' beliefs about their knowledge of the terms 'electrical' and 'compress' changed the most (40% vs. 76% and 36% vs. 71%, respectively). Students' perceptions of their knowledge of the term 'kinetos' changed the least as a result of instruction (0% vs. 2%).

Statistically significant differences were evident in students' perceptions of their knowledge and ability to explain terminology for all four different categories of science terminologies (see Table 5). The greatest change in mean value from pre- to posttest occurred for new formal science terminologies (1.79 vs. 2.75). The least change in mean value from pre to post was evident in terms in the old formal science terminology category (2.58 vs. 2.73) (see Table 5). The greatest change in variation to the mean was present in the new formal science terminology category where the standard deviation about the mean decreased from 0.41 in the pretest to 0.26 in the posttest (see Table 5). Cohen's effect size values ($d = 2.78$, $d = 0.75$, $d = 0.59$, and $d = 0.87$) suggested a moderate to large practical significance (Cohen, 1988) for the statistically significant increases in students' perceptions of vocabulary knowledge.

Student's perceptions of vocabulary and close reading strategies

As shown in Table 6, students had favorable beliefs about the close reading strategies and their learning. A high percentage of the participants believed that they could use close reading strategies on their own to learn difficult content (78%) and could teach another student how to close read science text (70%). Many students believe that the close reading strategy was important for their development of knowledge (69%). Finally, most students believed they would use close reading strategies to answer difficult science questions (68%) and on state-mandated science tests (83%).

As shown in Table 7, many students believed vocabulary strategies were important for their future success (68%). Students also had favorable attitudes toward the different

Table 6. Students' perceptions of close reading strategies used to learn science content.

Question	Agree	Undecided/ uncertain	Disagree
The close reading strategy helped me learn about vocabulary	69%	18%	14%
If I had to read about new and difficult science ideas, I could use strategies from class to learn new vocabulary	78%	14%	9%
I *cannot* understand science when reading text even if I try hard	11%	14%	75%
The close reading strategy will be useful in solving everyday life problems that involve reading	50%	33%	18%
I could teach another student how to close read a section of text	70%	23%	8%
I could help someone learn science from reading a difficult test	64%	24%	13%
I will use the close reading strategies when answering difficult test questions	68%	26%	6%
I will use the close reading strategies when answering challenging items on the State Level test	83%	13%	5%

Table 7. Students' perceptions of vocabulary strategies used to learn science content.

Question	Agree	Undecided/ uncertain	Disagree
I am confident that I can use vocabulary strategies from class on my own to understand new science terms	71%	20%	9%
Understanding science vocabulary will help me understand the world around me	61%	31%	8%
We did a lot of interesting vocabulary activities in science class	58%	28%	15%
Learning new science vocabulary is *not* important for my future success	8%	21%	71%
The science vocabulary pretest was helpful for introducing new terms before I learned them	63%	29%	9%
Drawing pictures to illustrate new terms helped me learn science vocabulary	64%	15%	21%
Taking notes was important for helping me learn new science vocabulary	70%	20%	10%
Watching videos helped me learn new vocabulary	74%	17%	9%
Learning new science vocabulary is important for my future success	68%	28%	5%

vocabulary strategies implemented. For example, the following data indicate percentages of students who thought the vocabulary strategies helped them learn: drawing pictures (64%), watching videos (74%), taking notes (70%), and completing a pretest (63%).

Content achievement

As shown in Table 8, the test population outperformed students from the national data set for all items (see Appendix A) and topics (see Table 8). For 7 of the 8 items (items 1–6, and 8), students in the test population did significant better than the national data set. The statically significant differences were due to the students' scores in the test population being higher than expected when compared to the national data set. The greatest difference (59% difference) between student and the national data set scores was evident for item 8 that focused on the relationship between mass, velocity, and kinetic energy (motion energy). Ninety-five percent of students vs. 36% of the national data set accurately answered this item. Other notable differences occurred for items 2 (51% difference, 42% student population vs. 93% national data set), item 4 (42% difference, 53% student population vs. 95% national data set), and item 5 (42% student population difference, 56 vs. 98% national data set). The least difference between student scores and the national data set was for item 7. There was a 10% difference between student scores and the

Table 8. Comparisons of student content achievement to national data set.

Item	Topic	National data set ($n = 1000$)	Test population ($n = 41$)	Chi-squared test
1	Relationship between mass, velocity, and kinetic energy (motion energy)	58%	95%	χ^2 (1) = 23.56, $p < .01$
2	Relationship between mass, velocity, and kinetic energy (motion energy)	42%	93%	χ^2 (1) = 41.21, $p < .01$
3	Relationship between mass and gravitational potential energy	48%	88%	χ^2 (1) = 26.02, $p < .01$
4	Kinetic energy (motion energy)	53%	95%	χ^2 (1) = 29.52, $p < .01$
5	Relationship between mass, position, and gravitational potential energy	56%	98%	χ^2 (1) = 26.77, $p < .01$
6	Relationship between energy transformation, potential energy, kinetic energy (motion energy)	56%	98%	χ^2 (1) = 26.77, $p < .01$
7	Relationship between compression and elastic energy	53%	63%	χ^2 (1) = 1.62, $p > .01$
8	Relationship between mass, velocity, and kinetic energy (motion energy)	36%	95%	χ^2 (1) = 56.46, $p < .01$

scores for students from the national data set (63% student population vs. 53% national data set) (see Appendix A for the assessment items).

Comparisons among students' perceptions of vocabulary knowledge, perceptions of instructional strategies, and content knowledge achievement

There was considerable consistency between students' perceptions of vocabulary knowledge of terms (kinetic energy, potential energy, energy transformations, gravitational potential energy), and content achievement. For instance, on the posttest of perceptions of formal science terminologies (see Table 1), students had high confidence in their knowledge and ability to explain (88–100%) the following terms: kinetic energy, potential energy, energy transformations, gravitational potential energy, and elastic potential energy. A high percentage (88–95%) accurately answered the assessment items dealing with the following: relationship between mass, velocity, and kinetic energy (motion energy); the relationship between mass and gravitational potential energy, kinetic energy (motion energy); the relationship between mass, position, and gravitational potential energy; and the relationship among energy transformation, potential energy, kinetic energy (motion energy) (see Table 8). Sixty-three percent of students accurately answered the question on elastic energy and compression compared to 88% of students being confident that they knew and could explain these ideas (see Tables 1 and 8). There was also a link between students' beliefs about close reading and vocabulary strategies and their perceptions of vocabulary knowledge and content achievement. More than two-thirds of the students reported that close reading and the vocabulary strategies were important for their development of science knowledge (69% and 68%, respectively) (see Tables 6 and 7). In summary, there were solid connections between students' perceptions of vocabulary knowledge of terms, content achievement, and perceptions of instructional strategies.

Discussion, implications, and conclusions

A substantial amount of reform initiatives in the USA advocate for literacy instruction in science teaching at the middle level to promote enhanced learning outcomes (NCTE, 1996; NGA & CCSSO, 2010; NRC, 2011). This is the first study to our knowledge to examine the interplay between students' beliefs about their knowledge, assessment of knowledge, and a classroom culture that values students' beliefs about literacy strategies. Overall, the findings of this study highlight the powerful role literacy strategies have on learning and the strong relationship between students' perceptions of vocabulary knowledge and content achievement. The literacy strategies helped students learn science content and contributed to their perceptions of vocabulary knowledge.

One important result of this study that expands the current literature based on interdisciplinary science teaching is related to the promotion of students thinking about their developing science understanding (e.g. perceptions of vocabulary knowledge). Studies have investigated direct instruction (e.g. Anderson & Nagy, 1991), providing multiple exposures to content (e.g. Stahl, 2005), and using terms in multiple contexts (e.g. Beck et al., 2002) on vocabulary knowledge gains. In addition, some research shows that there is a link between students' estimates of their performance and grades in school (Kuncel et al., 2005). This is the first study to our knowledge to take a more nuanced view to focus on students' perceptions of vocabulary knowledge for very specific content.

The findings show that there was considerable consistency between students' beliefs that they knew and could explain new terminologies (i.e. perceptions of vocabulary knowledge) and content achievement. For instance, the large effect size (by more than two and a half standard deviations, $d = 2.78$) strongly supports that the vocabulary instructional strategies had a considerable practical impact on students' perceptions of their knowledge of 'formal science terminologies'. The achievement tests indicate that a majority of students learned the intended content. These results highlight the importance of metacognitive awareness on learning and concur with research showing a link between engagement and achievement (e.g. Gregg & Sekeres, 2006; Guthrie et al., 1996; Hattie, 2009; Yates et al., 2011).

Another main finding is that the close reading and vocabulary strategies strongly support students' developing understanding of many science terminologies. Many students came into instruction believing that they held accurate knowledge and ability to explain both the 'old formal science terminology' and 'relationship terminology' categories. The close reading and vocabulary instruction had a significant impact on their development of even more accurate science understanding. The important influence of the instructional strategies on students' perceptions of vocabulary knowledge is supported by the moderate to large effect sizes for these categories. The vocabulary strategies had a large positive influence on students' perceptions of 'Old Formal', 'Relationship', and 'Other' terminologies by a magnitude of more than half a standard deviation ($d = 0.75$, 0.59, and 0.87, respectively). Similar to the 'word walls' researched by Yates et al. (2011), thinking about terminologies overtime and in new contexts increased students' perceptions of their developing understanding.

In terms of content achievement, students outperformed the national data set on all eight content test items. The literacy strategies were a viable way to help students learn the intended content. Thus, this study reiterates the findings of substantial research that literacy strategies improve academic achievement (Anderson & Freebody, 1981; Anderson & Nagy, 1991; Baumann & Kameenui, 1991; Beck et al., 2002; Stahl, 2005).

The perceptions of vocabulary knowledge assessments required students to reflect on their knowledge and consider the types of literacy strategies that helped their learning. The perceptions of vocabulary knowledge assessments allowed students to evaluate and reflect on the content. For students, their thinking about their knowledge (metacognition) could be a powerful strategy to promote deeper levels of self-regulatory learning. For example, if a student realized they did not know and understand a term after instruction they could spend time honing in and reviewing the specific content or may need additional instructional strategies to develop confidence in their knowledge. Moreover, the literacy strategies (perceptions of vocabulary and close reading) tests allowed students to reflect on the practices that facilitated their knowledge development and ability to understand difficult science content. For instance, many students realized that close reading strategies can be helpful when encountering new and difficult content. Students could use close reading strategies such as highlighting and annotating to help them learn from text passages and correctly answer test questions. Similarly, students reflected on the importance of integrative vocabulary strategies on their knowledge. Students could use integrative vocabulary such as creating visual representations for concepts as a successful method for learning new science content in different contexts. Part of the connection between perceptions of vocabulary knowledge and content achievement is due to the fact that they both require metacognitive awareness, that is, the ability to reflect on definitional and contextual information and apply knowledge in a variety of settings.

While the main findings fill an important and missing gap in understanding students' perceptions of vocabulary knowledge and strategies used to teach science, more research is needed that investigates the relationship between students' perceptions of vocabulary knowledge and reading comprehension. One limitation to the implications of the findings is that this study only sought out to ascertain students' perceptions of vocabulary knowledge before and after instruction and content achievement on a select few learning objectives. More research is needed that explores whether students learned science vocabulary assessed in the perceptions of vocabulary knowledge pre- and posttest. Vocabulary content tests for each item on the pre- and posttest would begin to fill the gap in understanding the relationship between students' perceptions of vocabulary knowledge and content knowledge for specific terminology. A second limitation to this study is the explicit relationship between students' perceptions of knowledge and reading comprehension was not the focus of the research. Understanding the relationship between perceptions of vocabulary knowledge, reading comprehension, and content achievement would better help students more effectively self-regulate cognitive activities they use to learn from challenging science texts. More studies are needed that investigate how students question, synthesize, visualize, and represent (mentally and visually) vocabulary while they read challenging technical text to develop knowledge. In this regard, qualitative studies would help describe the mental processes students use to learn vocabulary from reading.

In conclusion, for teachers interested in implementing literacy strategies and teacher researchers interested in interdisciplinary teaching, the results of this study provide a better understanding of the types of strategies that students believe encourage vocabulary learning. A necessary component of effective science instruction takes into account students' perceptions of vocabulary knowledge and learning in order to promote more self-sufficient, independent learners (Bransford et al., 2000). This is one of the first studies to our knowledge aimed at better understanding the use of literacy strategies to develop students thinking and science knowledge. The main findings highlight the prominent place that literacy strategies and metacognition should hold in a science course. To provide quality science learning, classroom teachers must understand the vocabulary demands placed on students and perceptions about teaching and learning that are important for the development of knowledge.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix A. Content assessment items

Questions
(1) A boy and a girl are sledding down a hill. The boy and the girl weigh the same, and they are using sleds that weigh the same. If the boy and girl are sledding at the same speed, which child has more kinetic energy? (a) The boy has more motion energy. (b) The girl has more motion energy. (c) *Both of them have the same amount of motion energy*.[1] (d) Neither the boy nor the girl has any motion energy.
(2) Object 1 and Object 2 are traveling at the same speed, but the motion energy (kinetic energy) of Object 1 is greater than the motion energy of Object 2. Does Object 1 weigh more than, less than, or the same as Object 2? (a) *Object 1 weighs more than Object 2*. (b) Object 1 weighs less than Object 2. (c) Object 1 weighs the same as Object 2. (d) More information is needed to compare the weights of the objects.
(3) A student places two books on a table. One book weighs less than the other book. Which book has less gravitational potential energy? (Consider the reference point to be the floor.) (a) *The book that weighs less has less gravitational potential energy*. (b) The book that weighs more has less gravitational potential energy. (c) Both books have the same amount of gravitational potential energy. (d) Neither book has any gravitational potential energy.
(4) A girl and a boy are each holding a ball. The girl throws her ball, and the boy drops his ball. Which statement describes the motion energy (kinetic energy) of the balls while they are moving through the air? (a) *Both the ball that was thrown and the ball that was dropped have motion energy*. (b) The ball that was thrown has motion energy, but the ball that was dropped does not. (c) The ball that was dropped has motion energy, but the ball that was thrown does not. (d) Neither the ball that was thrown nor the ball that was dropped has motion energy.

(*Continued*)

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Questions
(5) A person hangs three pictures on the wall. The pictures all weigh the same. Picture 1 and Picture 2 are at the same height above the floor. Picture 3 is directly below Picture 1. (a) *Pictures 1 and 2 have the same amount of gravitational potential energy*. (b) Pictures 1 and 3 have the same amount of gravitational potential energy. (c) Pictures 2 and 3 have the same amount of gravitational potential energy. (d) All of the pictures have the same amount of gravitational potential energy.
(6) Is energy transformed while a rock is falling from a cliff? Explain. (a) Yes, motion energy (kinetic energy) is transformed into gravitational potential energy as the rock falls. (b) *Yes, gravitational potential energy is transformed into motion energy (kinetic energy) as the rock falls*. (c) No, because the rock lost all of its gravitational potential energy once it started to move. (d) No, because one form of energy cannot be transformed into another form of energy.
(7) A student compresses a spring. How does the elastic energy of the spring change when the student compresses it? (a) *The elastic energy of the spring increases when the student compresses it*. (b) The elastic energy of the spring decreases when the student compresses it. (c) The elastic energy of the spring does not change when the student compresses it. (d) More information is needed to tell how the elastic energy changes.
(8) Two cars are traveling down a road at the same speed. Car 1 has more motion energy (kinetic energy) than Car 2. Does Car 1 weigh more than, less than, or the same as Car 2? (a) *Car 1 weighs more than Car 2*. (b) Car 1 weighs less than Car 2. (c) Car 1 weighs the same as Car 2. (d) More information is needed to compare the weights of the cars.

[1]Correct selection in italics.