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Pathway Towards Fluency: Using 'disaggregate instruction' to promote science literacy

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RESEARCH REPORT

Pathway Towards Fluency: Using 'disaggregate instruction' to promote science literacy

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This study examines the impact of *Disaggregate Instruction* on students' science learning. *Disaggregate Instruction* is the idea that science teaching and learning can be separated into conceptual and discursive components. Using randomly assigned experimental and control groups, 49 fifth-grade students received web-based science lessons on photosynthesis using our experimental approach. We supplemented quantitative statistical comparisons of students' performance on pre- and post-test questions (multiple choice and short answer) with a qualitative analysis of students' post-test interviews. The results revealed that students in the experimental group outscored their control group counterparts across all measures. In addition, students taught using the experimental method demonstrated an improved ability to write using scientific language as well as an improved ability to provide oral explanations using scientific language. This study has important implications for how science educators can prepare teachers to teach diverse student populations.

Keywords: *Discourse; Language; Scientific literacy*

In this study, we focused on students' science learning and the language used to introduce scientific ideas. The way we come to understand the world is rooted in the language resources used to articulate our understandings (Vygotsky, 1986). As a result, what a young person is able to conceptualize is inherently connected to the types of language resources available to articulate that understanding.

Given that assumption, science education can be thought to live at the intersection of conceptualization and articulation. In many ways, students' ability to describe a phenomenon is constrained by the science language at their disposal (Brown, 2004; Fang, 2004; Varelas, Pappas, & Rife, 2006). Take, for example, an

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excerpt from a conversation with African-American students in Oakland, California. When asked to explain why they have never seen an obese competitive marathon runner, the following conversation ensued:

D'Andre:	It's basically because they be sweatin'.
Teacher:	That's good. What does sweat have to do with it?
Tanisha:	It's because they always be hot. They be hotter than everybody else. My cousin always be sweatin'.
Steve:	It's cause they fat Blood! [laughter] They get hot and they always be sweatin' … even if they just walkin' up the stairs.
D'Andre:	Naw! It's like this. It's like if you set a block of ice out. Out on the curb. The ice don't just melt. First, it just turns into water. Then, the water it disappears into steam. It's like that. It don't be no fat marathon runners because when they run, they melt the fat and they body use the fat and it burns off.

This excerpt provides an example of how conceptualization and scientific articulation intersect. First, D'Andre's description of the process of using fat for energy is void of the traditional scientific terminology that provides an ability to distinguish between types (Anabolic and Catabolic) of metabolism. Despite not using those terms, he expresses a tenuous understanding of the way fat is used for energy. Without using canonical scientific terminology, he explains how fat is converted to another form for human use and is subsequently used for energy purposes. His selection of an analogy to explain this process provides him a resource for explaining phenomenon, but does not allow him to benefit from the taxonomical and organizational specificity of scientific language.

The challenge that emerges in analyzing the value of this excerpt is two-fold. First, D'Andre's language signals his Discursive Identity (Brown, 2004; Brown, Reveles, & Kelly, 2005). Brown et al. (2005) used the notion of Discursive Identity to explain how individuals use language to signal and interpret group membership. If we apply a Discursive Identity analysis to the excerpt we can ask whether his reluctance to use science language is a product of his desire to maintain the identity that is signaled through his language or an indication of his inability to use science language. Without a lens to analyze the sociocultural implications of language use, scholars are left to assume that one's use of science language is merely a matter of knowledge.

Second, D'Andre's use of language does not reflect a complete lack of cognitive understanding. There is a dichotomy between the conceptual understanding and linguistic understanding that is present here. He understands that metabolic processes involve physical changes. Although he does not describe the differences between anabolic and metabolic activity, through his analogy he demonstrates a tenuous understanding of this process. However, he does not have a clear understanding of the idea nor does he have an understanding of the science language that would enable him to denote the subtle differences in the types of metabolic activities. In learning to use science language, he would benefit from the thematic and organizational resources embedded in being able to "talk science" (Lemke, 1990).

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When science teaching is explored from a perspective that values teaching students to "talk science," examples like the one above provide insights into the need to develop pedagogy that incorporates academic language instruction. We propose a model that incorporates an immersion approach to science teaching. In foreign language courses, students learn new terms for familiar concepts. In doing so, teachers regularly define the norm for communication (e.g., speaking exclusively in Spanish). In contrast, learning science involves learning new language that represents new concepts, without the benefit of having language norms defined. The combined need to learn the concepts and language of science makes science learning particularly contentious.

In addition to the difficulty of merely learning new language practices, the subtle ways language cues cultural membership can also have an impact on students' ability to learn science (Brown, 2004, 2006). Research on science education has indicated how language impacts students' sense of belonging in science and their Discursive Identity among their peers (Brown, 2004, 2006; Gilbert & Yerrick, 2001; Varelas & Pappas, 2006). In light of the dynamic impact of language on science learning, this study examines how teaching from an approach that disaggregates teaching into conceptual and language components impacts students' learning.

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Theoretical Framework

The theoretical framework that guides this study attempts to synthesize seemingly competing frameworks on the role of culture and science learning. Several scholars focus their attention on identifying the conflicts between students' home cultures and their impact on science learning (Gilbert & Yerrick, 2001; Parsons, 1997; Wandersee & Griffard, 1999; Yerrick, 2000). Others challenge the research community to identify continuities between students' culture and the culture of science (Hrabowski & Maton, 1995; Jones, 1997; Seiler, Tobin, & Sokolic, 2001; Tobin, Smith, & Mackenzie, 1999). Our work attempts to extend both areas by proposing an intersection between these two approaches.

First, we use research on cultural conflict to highlight the role of science language as a central component in the classroom. The apparent conflicts between student cultural language and the language valued in science teaching can be used as a resource if instruction is separated into conceptual and language components. Second, we propose the idea of *Disaggregate Instruction* as a way to promote the conceptual continuities that have been discussed in past scholarship (Warren, Rosebery, & Conant, 1994; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Although past research has proposed focusing on academic language instruction, our work extends this research by suggesting that disaggregating instruction can potentially reduce the sociological impact of language and identity and improve student learning. Although we believe this project has the potential to impact both identity and learning, the scope of this study merely allows us to assess students' learning outcomes.

Studies of Cultural Conflict

Several studies in science education effectively identified the cultural conflict between students' home culture and that of the science classroom (Gilbert & Yerrick, 2001; Lee & Fradd, 1998; Parsons, 1997; Wandersee & Griffard, 1999; Yerrick, 2000). This area of research isolated the conflict on several areas including studies on the role of cultural conflict in learning (Gilbert & Yerrick, 2001; Lee, 2005; Wandersee & Griffard, 1999), as well as conflict between teachers' and students' attitudes (Atwater, 1995; Parsons, 1997). Gilbert and Yerrick (2001) discovered how students were challenged to balance dueling cultural influences. They suggested that students had to choose attaining symbolic membership in a "Marginalized Sub-Culture" if they chose success in the science classroom. That type of participation was seen as "trying to be of another race" (p. 584). Wandersee and Griffard (1999) suggested that students' disengagement with science was connected to cultural conflicts that led to greater interest in social interaction than academic performance, sustained confidence without academic competence, and cognitive passivity.

Other studies of cultural conflict identified how these conflicts impacted both teacher performance and student learning (Atwater, 1995; Parsons, 1997; Griffard & Wandersee, 1999; Sorge & Newsome, 2001). Several studies explored how attitudes of African-American students impacted their learning (Atwater, 1995; Parsons, 1997), while other studies highlighted how teachers' attitudes about minority students affected students' science learning (Brickhouse, Lowery, & Schultz, 2000; Brand & Glasson, 2004; Yerrick & Hoving, 2003). Atwater (1995) suggested African-American students' performance was closely connected to a complex set of attitudes. Griffard & Wandersee (1999) examined African-American females' science experiences and implicated cultural disengagement as a resource for promoting cognitive passivity. In general, this type of research attempted to draw a correlation between students' perception of science as counter cultural to their own cultural backgrounds. As a result, these scholars implicated cultural conflict as a source for a lack of motivation and interest among minority students.

Another prominent area of cultural conflict research examines how teacher attitudes negatively impacted minority students' learning (Brand & Glasson, 2004; Yerrick & Hoving, 2003). Brand and Glasson (2004) suggested that the teachers' ethnic backgrounds negatively impacted their pedagogy. Their experiences during the pre-service programs either confirmed or challenged stereotypical thought processes. Yerrick and Hoving (2003) identified teachers whose willingness to change their attitudes in response to their professional experiences benefited their ability to negotiate cultural conflicts. They also identified teachers who resisted recognition of cultural conflicts in an effort to reproduce their own educational experience. Overall, these studies share a common premise, which is to identify how conflicts in culture impact the teaching and learning of minority students.

Scholars of science education have also explored how cultural conflicts are made manifest in language practices of science (Hart & Lee, 2003; Lee, 2005, 2002; Moje,

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Collazo, Carillo, & Marx, 2001; Stoddart, Pinal, Latzke, & Canaday, 2002). In a review of research on English language learners, Lee (2005) suggested that conflicts that emerge in science language are embedded in the discontinuity between students' language and cultural practices when compared to those valued in science.

> Students from diverse linguistic backgrounds come to school with already constructed knowledge, including their home language and cultural values, acquired in their home and community environments. Such knowledge serves as a framework for constructing new understandings. However, some aspects of students' experiences may be discontinuous with science disciplines as traditionally defined in Western science. (p. 511)

Lee's perspective reflects a key paradigm in research on the role of language and culture in science learning. Her work highlights how language and culture have the potential to be in conflict with science learning. Moje et al. (2001) provided an example of this type of discontinuity as they examined how students' understanding of the idea of "quality" water differed dramatically from that of the scientific notion. In their work, issues of potability, salinity, and overall pureness were masked in the cultural differences lost in the transition from one language to another. Stoddart et al. (2002) suggested that the language differences between science and Spanish are so significant that science language should be taught as if it were a second language. Overall, the discontinuity research associated with language acquisition suggests that students arrive at school with very specific language practices that lead to issues of cultural conflict in the classroom.

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Cultural Continuity and Science Learning

Research on minority students also promotes the understanding of cultural continuity. These studies urge educators to document ways to improve science by understanding the cultural resources students bring with them.

Some studies explore pedagogical interventions designed to improve minority students' learning (Hrabowski & Maton, 1995; Jones, 1997; Olitsky, 2007; Seiler et al., 2001; Tobin et al., 1999). Tobin et al. (1999) presented an analysis of pre-service teachers' training that advocated co-teaching as a means to support pre-service teachers teaching minority students in urban communities. Jones (1997) examined an informal approach to teaching agriculture that focused on the relevance of agricultural study that addressed the disinterest found in African-American participants.

Several studies examined using collaborative learning environments to promote learning for African-American students (Rahm, 2002; Tobin, Roth, & Zimmerman, 2001). Tobin et al. (2001) engaged in research that promoted co-teaching training for pre-service teachers as a way to develop a culturally relevant pedagogy for African-American students. Rahm (2002) suggested informal learning environments that served as fruitful locales for making science teaching culturally relevant. Hrabowski and Maton's (1995) work also implicated the role of alternative programs as a means to promote science achievement. They examined 69 students enrolled in The Meyerhoff Program and discovered that their participation led to significantly higher grade point averages for African-American students. Seiler et al.

(2001) found that students engaged in progressive scaffolding demonstrated an ability to engage in science language for diverse outcomes. They explained, "As educators, we must find ways to tap into cultural funds of knowledge that students possess that are already science-like" (p. 761). The collaborative efforts of this area of research propose the design of learning environments that find innovative ways to align minority student culture with the culture of science.

To extend this research, we propose the development of a theoretical position that can be assessed through causal research. We believe the notion of Disaggregate Instruction can extend the work of scholars who utilize the discontinuity framework (Atwater, 1995; Lee, 2002; Lee & Fradd, 1998) as well as research that seeks to promote cultural continuities (Warren et al., 1994; Warren et al., 2001). Disaggregate instruction begins with the assumption that cultural conflicts are embedded in differences between everyday cultural practices and those valued by science. To address these conflicts, teachers must separate teaching into a conceptual component and a language instruction component. In this disaggregating process, the initial teaching can use the language and culture of minority students as a resource for helping them understand science ideas as a precursor for their learning the language of science. Applying a disaggregate framework for science pedagogy has the potential to extend contemporary science research by offering a way to recognize the potential challenges in student culture while using them as a resource to promote student learning.

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Disaggregate Instruction and Science Learning

A primary assumption that guides the concept of Disaggregate Instruction is the idea that scientific terms are often used as proxies for scientific ideas. The language of science is a resource used to symbolize physiological and spatial relationships that are organized through a well-structured language system. The science words and symbols systems provide access to conceptual depth, but are not the only way to represent the scientific ideas. Although the language structure of science provides speakers with an efficient mode of communication, it is not the sole mode of communication. One's ability to appropriately use science language can reflect his or her science knowledge on two levels: conceptual and discursive. Our work synthesizes theoretical perspectives rooted in physics education and science education research to argue the need for a disaggregate approach to teaching (Arons, 1973, 1983; Brown, 2004; Brown et al., 2005; Lee & Fradd, 1998; Varelas, Becker, Luster, & Wenzel, 2002).

Physicist A. B. Arons (1983) introduced the need for Disaggregate Instruction by outlining the learning dilemma posed by teaching concepts and language simultaneously. He contended that teaching must avoid using complex terminology to introduce phenomena to students. Arons described science teaching as "little more than an incomprehensible stream of technical jargon, not rooted in any experience accessible to the student himself, and presented much too rapidly and in far too high a volume for the assimilation of any significant understanding of ideas, concepts, or theories" (Arons, 1973, p. 772). Arons' perspective challenged science educators to consider how presenting students with new concepts taught with science language risks presenting science ideas in an incomprehensible language.

Lemke (1990) affirmed Arons' concern by arguing that construction of a scientific understanding takes place via an opportunity to "talk science". He described how students do not necessarily enter school able to engage in science language; rather, it is the job of the teacher to introduce the intricacies of the language and to scaffold students to join this conversation through connection to everyday experiences. So, in order to reach conceptual understanding, teachers need to teach science language explicitly and provide opportunities to practice it.

More recently, research has proposed theoretical frameworks that support the idea of Disaggregate Instruction by calling for the synthesis of cultural frameworks (Lee & Fradd, 1998). Lee and Fradd proposed Instructional Congruence as a framework to help students' transition from the language and cultural practices of their home to those of the science classroom. To accomplish this, they afforded teachers the responsibility to learn the cultural and linguistic backgrounds of students as a fundamental step to bridging home language with the science language of the classroom. If science is presented without a rich consideration for how students come to interact with the language of science, science teaching can marginalize students whose language practices are vastly different from those used in science classrooms. Therefore, taking a Disaggregate approach to teaching has the potential to support the identification of instructional congruence.

However, science education research is beginning to examine the impact of building synergy between students' language and science language (Brown, 2004, 2006; Reveles, Cordova, & Kelly, 2002; Varelas et al., 2002). Reveles et al. (2002) examined a teacher's strategic approach to showing students a vision of how their everyday terms were similar to those used in science. The teacher in their study promoted students' understanding of scientific language by drawing parallels between their everyday practices and the practices of science. Students were given opportunities to explain and discuss science ideas in everyday terms and were also explicitly made aware of the transitions in their modes of instruction (from conceptual instruction to language instruction).

Collectively, the implications of this study lead to the notion that science must be taught with respect to language learning, and that teachers must engage in instruction that separates the conceptual and language components of science in an effort to decrease the problematic nature of academic language learning. We contend that improved science instruction (which leads to science fluency) must seek to actively deconstruct science teaching into conceptual and language components as a means to improve students' conceptual understanding and to promote students' discursive identity development (Brown et al., 2005).

Learning Science Language and Discursive Identity

A second lens that supports our call for Disaggregate Instruction involves the role of student identity. Research examining the relationship between students' language,

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identity, and classroom learning exists largely outside of the science education community (Fishman, 1989; Gee, 1999; Malcolm, 1989; Starfield, 2002; Wenger, 1999). Collectively, these scholars describe language as a component of students' identity and suggest that as students learn new languages, they must take on identities associated with those languages (Brown et al., 2005; Fordham, 1999; Hill, 1999).

We propose the inclusion of a theoretical lens that values the role of *Discursive Identity* in science teaching and learning. A *Discursive Identity* is a theoretical lens that allows us to understand how people use verbal cues to interpret "who" someone is and how people send verbal cues to position themselves as a particular type of person (Brown, 2004). During linguistic exchanges, people use genre selections, word choices, and tone selections to sound like a particular type of person, or use those cues to interpret who we understand someone to be after hearing their speech. Although this interaction may be subtle, the use of these cues is dynamic because it reflects both who we perceive people to be and who we would like to be perceived as on the basis of the use of language.

In science classrooms, Discursive Identity can be used as a lens to understand how individuals perceive written, mathematical, symbolic, and spoken languages in science. In general, people view language as symbolic of cultural membership; therefore, when they encounter alternative languages, these encounters may signal identity mismatch (Agar, 1994; Brown, 2004). Particular styles of language can be attributed to a particular gender or ethnic group (Ball, Williams, & Cooks, 1997; Rickford, 1999). As a result of students' understanding of the meaning of using certain language genres, certain language practices can become taboo or representative of alternative cultures. Applying this lens to an analysis of students' science learning leads to a consideration of ways to restructure science teaching to help reduce potential conflicts in discursive identity. Without an ideology that carefully examines the relationship between language, identity, and student learning, scholars make the erroneous assumption that participation in science occurs free from cultural implications.

Literacy research can provide a valuable lens for understanding how to address the impact of student identity and academic language learning. Lee's (2006) Cultural Modeling framework offers insight on instruction that seeks to decrease the impact of identity appropriation (Hull & Shultz, 2001; Lee, 2006; Mahiri, 1998). Lee describes this framework by explaining: "The aim is to examine what may be points of synergy and difference between problem solving in an everyday domain and problem solving within a subject matter" (p. 308). Such an approach has the potential to promote student learning by allowing students to gain a generic understanding of the content and to see the synergy between everyday and scientific explanations of a phenomenon. Disaggregate Instruction can be considered a type of cultural modeling due to the manner in which Disaggregate Instruction can allow room for students' voices early in the instructional process, but will also scaffold students towards the use and understanding of science language.

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Research Questions

Given our theoretical position, this study seeks to address the following research questions: If students are taught science using a Disaggregate Instruction approach that initially teaches content without dense language and follows with intensive language instruction, how will such an approach affect students' ability to reach the understanding of a concept when questions are asked in both everyday language and science language? If students are taught in this manner, what will an assessment reveal about their conceptual understanding relative to students not taught with the same approach? How will a Disaggregate approach to teaching impact students' ability to communicate their understanding of a science topic using scientific language?

Methodology

We conducted this study at an ethnically diverse elementary school in northern California, USA. Holloway Elementary School[1] has an average population of 723 students (*between 2002 and 2006*), including a demographic makeup comprising 55% Hispanic/Latino students, 18% African-Americans, 12% Caucasians, 12% Filipinos, 8% Asians, and 1% Pacific Islanders. Within Holloway's student population, 50% of the students participate in free or reduced-price lunch programs.

Holloway students come from a diverse set of language backgrounds. The school classifies 77% of the students as English language learners based on their primary home language. Although we were able to identify students' home language, we were not provided access to reports of students' language ability. Therefore, determining students' relative ability to acquire academic language was difficult. Additionally, such a categorization does not allow a thoughtful analysis of students' relative language acquisition abilities across multiple domains (*Reading*, *Writing*, and *Speaking*). Given our inability to adequately classify students based on their language abilities, we chose to focus our analysis on the ability of students from diverse cultural backgrounds to acquire scientific language.

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Participants

Forty-nine fifth grade students from two fifth grade classrooms participated in this study. Of the 49 students who participated in the study, 30 spoke Spanish as their primary home language, while 19 spoke English as their primary home language. Language categorizations of that nature are critical to the outcome of this study, given our objective of assessing students' relative ability to acquire scientific language. Therefore, we randomly assigned students to either treatment or control groups without respect to language abilities to assess the impact of our instructional approach on their academic language learning. Twenty-eight of these students were male, and 21 were female. To ensure that students' computer skills were not a significant contributor to the study's outcome, the classroom involved in the study was selected for its regular use of computers. The class was a member of the e-Learning^{TM} community, which regularly used the Internet as an instructional resource.[2]

Instructional Intervention: Disaggregate instruction

This study is founded on the idea that students' science learning is best achieved when students are taught by separating everyday and scientific language (Disaggregate Instruction). In an attempt to examine this, we used a teaching approach that separates teaching into two components: conceptual instruction and language instruction.

This approach, entitled the Directed Language Approach to Science Instruction (DDASI), involves a four-stage approach to teaching science based on the use of everyday scientific language.

Stage 1, the Pre-Assessment Instruction Phase, involves using a query-oriented approach to introducing the ideas of science. This stage of the lesson allows students to identify their understanding of the phenomena being discussed and allows the teacher to understand what students' preconceptions of the concept may be. For example, a lesson on photosynthesis may begin by examining how students answer the question, "What things do *all* plants need to grow?" As students answer those questions, the teacher can use formative assessment to determine what students need to know.

In Stage 2, the Content Construction Phase, the teacher introduces students to the accurate versions of the content discussed in Stage 1, without using the detailed language and overbearing technical language associated with science. The teacher can begin to ensure that the general concept is understood, while using students' own language resources. Additionally, manipulation of materials can occur at either the pre-assessment or content construction phases, as a means to promote student inquiry. Returning to our example, a teacher may want to address the misconception that dirt is a requirement of all plants' growth. Through activities and instruction, the students may develop an understanding of photosynthesis in everyday language that suggests that photosynthesis occurs when plants have "sunlight," "the air that humans breathe out," and "water."

During Stage 3, the Introduction of Explicit Language Phase, the teacher scaffolds students' use of scientific language by introducing students to the specific language used to describe phenomena. At this point, the teacher introduces the students to the specific language of the content and requires them to build these terms into their vocabulary by providing them with opportunities to use the language in classroom talk and written assignments. With the teacher's assistance, the rules for language use are clear and explicit. In our example, a teacher may ask students to use terms like "carbon dioxide" and "photons" instead of "sunlight" and "the air that humans breathe out." This phase helps students see the continuity between everyday ways of understanding phenomena and scientific ways of explaining the same phenomena.

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In the Final Stage, the Scaffolding Opportunities for Language Phase, the teacher provides students with opportunities to articulate their understanding of the phenomena. This stage uses assessment activities to create opportunities to write about and explain the concepts using the technical language of science. In this phase, students are asked to discuss the phenomena individually (either by writing or speaking), using the technical terminology of science. These language-building activities are free from the teacher's assistance, thus requiring the students to build their own conceptual and linguistic understanding. With the exception of the language used, the content and presentations of the two versions of the program were identical.

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The Technology

To isolate the impact of teacher effect on this study, we designed a web-based science lesson using two different versions. The first version merged conceptual learning with scientific language learning (*control version*). We refer to this type of instruction as "aggregate" pedagogy because the conceptual and linguistic components of the concept are taught together.

The second version used the DDASI approach as a means of separating conceptual and language learning *(treatment version)*. We refer to this mode of instruction as the "disaggregate" pedagogy because the conceptual and linguistic aspects of instruction are separate. This approach is based on the theoretical assumption that if students develop a fundamental understanding of the idea first, they will have greater opportunity to understand the concepts and employ scientific language when it is introduced later in the instructional process.

To ensure that the website offered an adequate environment for delivering instruction, the site included simulations of actual lesson plan activities. We designed and taught a lesson on photosynthesis and used this lesson as a model for designing the website. For example, we attempted to replicate the experiment conducted in class by using a simulated version of the experiments that included audio of the students' most common responses and predictions. Additionally, we simulated a microscope activity by allowing students to use a virtual microscope that magnified images by clicking on the images. In our attempts to ensure that the website provided accurate simulations of the students' use of microscopes, we used animation to provide magnified images of the leaf that resembled the students' classroom experience. Overall, the website provided students with instruction that included reading, experiments, and simulated discussions that were designed to mirror the authentic conversations that occurred in the class.

Procedure

For the purpose of this study, 49 students were randomly assigned into either the treatment group (Disaggregated) or the control group (Aggregated) stratified by gender. Prior to the study, all participants were administrated a pre-test which consisted of 18 multiple-choice questions and 10 open-ended questions. After the pre-test, students received individual science instruction using one of the two versions of the computer program. Students in the treatment group used the treatment version of the program that taught the concepts of photosynthesis in everyday English prior to introducing scientific language. Students in the control group used the control version of the program that taught the same concepts in both everyday and scientific language simultaneously. The software itself required nearly 3–4 hours to complete. To prevent teacher bias, the instruction was delivered by a computer program, and teachers served only as facilitators. After completing the instruction, all participants took a post-test which was the same as the pre-test and participated in individual interviews with the researchers.

To assess students' differential learning gains, we used a pre-test/post-test control group design. We explored students' performance on three dependent measures, including students' overall score, students' score on questions asked in everyday language (disaggregate), and students' score on questions asked using science language (aggregate). Prior to the study, we administered a pre-test which consisted of 18 multiple-choice and 10 open-ended questions. Ten of the 18 multiple-choice questions were written in everyday English (*disaggregate*), while eight were written using scientific language (aggregate). For example, a disaggregate question asked what plants release while they are making their own food, and then provided multiple choices, such as *water*, *air that humans breathe out*, *air that humans breathe in*, and *dirt*. The aggregate questions asked students to describe the products of photosynthesis and offered *oxygen*, *stomata*, and *photons* as possible choices for the answers. One point was given for each correct answer, and the total possible score for the multiple-choice test was 18 points.

Students also received 10 open-ended questions that required them to provide written explanations of photosynthesis. Half of the questions were asked using everyday language, and half were constructed to assess their conceptual understanding in scientific language. For example, the open-ended question in everyday language asked students to write about how plants grow, while the open-ended question in scientific language asked students to explain how photosynthesis occurs.

Coding Responses to Open-Ended Questions

To assess students' ability to write, we designed a rubric. One point was assigned for correct concepts, regardless of the genre of language being used. In contrast, we assigned a score of "0" in instances where there is no response or where an incorrect answer is offered. The maximum score for each question ranged from 1 to 7 depending on the number of concepts being assessed. The highest possible score for conceptual understanding in everyday language was 29.

We used a second scoring system to assess students' conceptual understanding as expressed through *scientific language*. We assigned one point for each correct concept answer written in scientific language. We assigned a score of "0" for instances where

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students left the question blank and for questions that provided incorrect answers. We also assigned a score of "0" for a concept written in everyday language, when the question asked for the use of science language. The maximum score for each question also ranged from 1 to 7 depending on the number of concepts being tested. The maximum possible score for the use of scientific language was also 29. As each question was coded, the researchers were blind to the treatment assignment of each student. Any disagreements regarding scoring were resolved through discussions among the researchers.

Data from both the multiple-choice and open-ended questions were analyzed using the Statistical Software Program Package (SPSS) 11.0. The analyses of pre- and post-test scores between the treatment and control groups were conducted using independent *t*-tests. The effect size was computed using Cohen's *d*. All tests were two-tailed, and an alpha level of 0.05 was used for the statistical analysis. The reliability of both tests was analyzed using the Cronbach's Alpha coefficient. The reliability of the multiple-choice test was 0.76, and the reliability of the open-ended questions was found to be 0.70.

To promote the triangulation of data, the written products of pre-test and post-test were collected, and each student's interview was videotaped. This study represents the result of the pre- and post-test performance.

Our qualitative analysis used post-interviews to support the quantitative component of this study. The research team reviewed and corrected errors in all of the transcripts. We reviewed the transcripts to establish an initial set of coding categories. We then used HyperResearch Software™ to code each of the transcripts. To ensure the reliability of the coding, we assigned two team members to review each transcript. When coding consensus was not achieved, we met to address any discrepancies. The transcripts were coded blindly, which enabled us to mask the identity of control and experimental groups. Upon completing the coding, we engaged in a taxonomical domain analysis of the types of student responses (Spradley, 1980).

In our domain analysis we coded the data in two ways. First, we conducted a macro-level analysis of the types of language that the students were able to use. At this macro level, we used the Speech Act as our primary unit of analysis (Green & Wallat, 1981; Gumperz, 1982). A Speech Act assumes that individuals have the power to determine when, how, and to what extent they participate in a conversation. As such, any form of speech can be seen as a conscious and empowered action, or Speech Act. Given our assumption that students maintain the agency to determine when to begin and end their answers, and they choose how to speak during those answers, we used the Speech Act as our unit of analysis. Each time a student began to answer a question and subsequently chose to end their answer constituted a unit. We then analyzed these units based upon the types of nouns they chose to describe scientific phenomena. If they solely used science nouns in their Speech Act, we coded these as Science, while if they used everyday alternatives we coded using the Everyday language designation. If they used multiple genres in a single speech act, we coded these as Hybrid. Ultimately, using an analysis of a Speech Act and analyzing the types of language used provided us insights

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into how students used a diversity of linguistic resources in their description of phenomenon.

Our microanalysis of students' language involved a more detailed assessment of the students' language. In this analysis, we examined how students used the different genres of talk (Science, Everyday, or Hybrid) either correctly or incorrectly. To do this, we coded the data based on the genre of speech being used and then used the software to re-code whether the content was accurate or inaccurate when the students used the mode of language being analyzed.

To assess students' learning across multiple language types (Writing, Reading, and Speaking), we compared the results of the written assessments (multiple-choice and open-ended questions) with an assessment of their ability to speak using scientific language (interviews). To ensure that these interviews would be as natural as possible, we used a semi-structured approach to these interviews.

Using an interview protocol that posed questions using both everyday and scientific language, our semi-structured interviews utilized an open framework that allowed the interviewer to use probes to produce a more focused, conversational mode of communication (Kvale, 1996). To expand student opportunities to talk about science, we used probes to gain greater access to topics about which students demonstrated greater knowledge or interest.

Each of the interviews was videotaped, transcribed, and reviewed for accuracy. Subsequently, the research team used HyperResearch™ software to code the interviews to identify students' patterns of language use. The reviewers established a primary set of codes, and each interview administered was subjected to two tiers of analysis. After completing this initial analysis, we engaged in a secondary analysis of the codes emerging from the first analysis. Using a domain analysis approach, we created detailed taxonomies of the ways students in both groups were able to use scientific language after being administered the software.

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Analysis 1: Quantitative measures

Our quantitative findings are presented in the two components. First, we engaged in a comparative analysis of students' performance on pre-test and post-test measures. We examined the results of *t*-tests on the three types of student performance: (1) total performance on all questions, (2) performance on the questions measuring conceptual understanding in everyday language, and (3) performance on the questions measuring conceptual understanding in scientific language. Second, we conducted a comparative analysis of students' performance on the open-ended and multiple-choice questions. The results provided empirical evidence regarding the impact of the disaggregate science teaching.

Students' Learning Gains

We compared students' pre-test results in order to establish that all students were equivalent in both their prior knowledge and ability to use scientific language. The

Table 1. Comparison of pre-test scores between the treatment and control groups

	Achievement (max)	Group	*N*	Pre-test score (*SD*)	*t*	*p*
	A	B	C	D	H	I
1	Overall score (76)	Treatment	25	11.60 (*5.56*)	0.519	0.61
		Control	24	10.79 (*5.31*)		
2	Disaggregate score (39)	Treatment	25	6.76 (*3.60*)	0.180	0.86
		Control	24	6.58 (*3.24*)		
3	Aggregate score (37)	Treatment	25	4.84 (*2.61*)	0.885	0.38
		Control	24	4.21 (*2.38*)		

pre-test scores revealed that both groups of students attained similar scores across all three measures, and there was no significant performance difference between the two prior to instruction (Table 1).

Figure 1 provides an overview of the differences in students' pre-test and post-test performance. This figure provides a visual representation of the relative gains of the treatment and control groups. On both the pre-test and the post-test, students in both groups scored highest on questions designed to measure their conceptual understanding of photosynthesis in everyday language (disaggregate). In contrast, students' lowest scores were on questions assessing their conceptual understanding

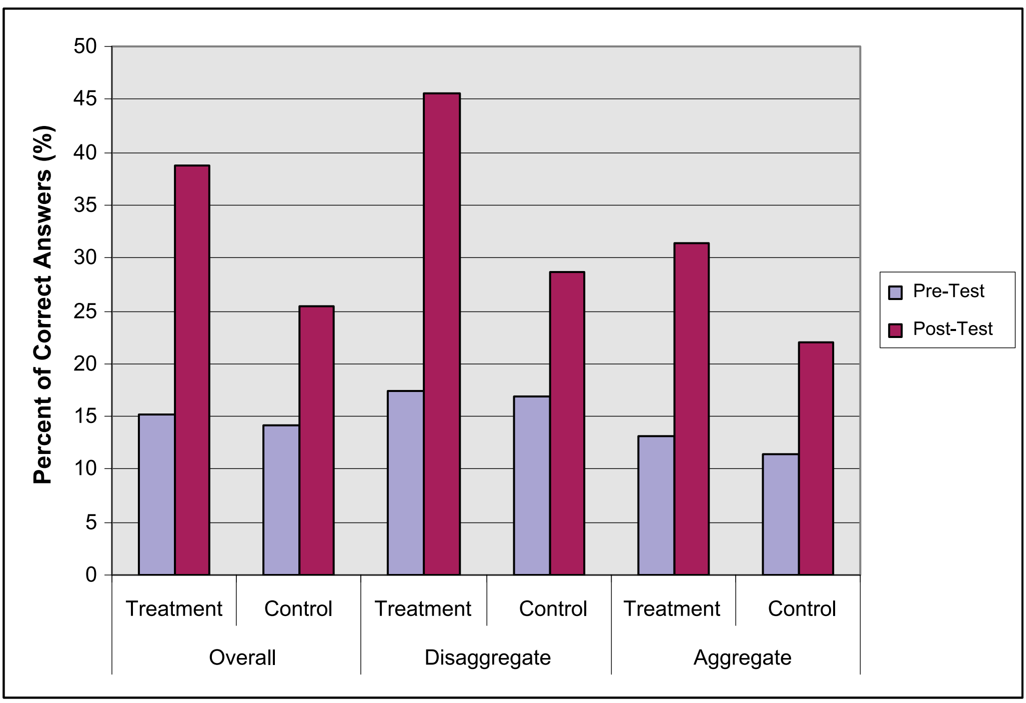

Figure 1. Comparison of pre- and post-test performance

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of photosynthesis in scientific language (aggregate). These findings further indicate the need to rethink science teaching and learning as processes that involve the learning of scientific content and scientific language. Furthermore, these results suggest that instructors must also consider ways of disaggregating the teaching of both content and language. Students' consistent underperformance on questions that asked them to demonstrate understanding of the topic in scientific language (aggregate) highlights the notion that when learning science, they are essentially being asked to learn both the content and the language of science.

Table 2 provides additional support for these findings with specific details of the differences between the learning gains of the two groups. We used paired *t*-test analyses to compare the pre-test and post-test scores of the treatment and control groups. Although both groups demonstrated significant increases on the post-test compared to the pre-test, the treatment group showed a greater learning gain across all measures compared to the control group. For example, Cell 1-G demonstrates that the treatment group's overall score increased by 23.42%, whereas the control group gained 11.18% on the post-test. The learning gains of the treatment group on both disaggregate and aggregate scores were nearly twice those of the learning gains of the control group. Given the almost identical pre-test mean scores for both groups, the greater gain of the treatment group's post score speaks volumes regarding the effect of the content-first approach. The results of the *t*-test were statistically significant (Cell 1-H) and a test for effect size revealed a strong effect of the treatment on students' overall performance (Cell 1-I). These findings provide further evidence that utilizing a content-first approach to teaching science provides students with a richer conceptual understanding (as expressed through their everyday understanding), in addition to equipping students to understand scientific language used to describe scientific phenomena.

When we contrast student performance across treatment types, Figure 1 further illustrates that students from the treatment group consistently outperformed students in the control group regardless of the question type. Although the scores of both groups were equivalent on the pre-test, indicating students' comparable understanding of the concepts in both everyday language and scientific language, the differences in students' post-test scores emphasize the impact of the treatment. That is, students in the treatment group significantly outperformed the control group students overall. Table 2 shows that the treatment group achieved a mean score of 29.40, whereas the control group achieved a mean score of 19.29 on the post-test (Cell 1-E). In particular, the difference between the two groups was the greatest when students were asked to demonstrate their conceptual understanding of scientific phenomena in everyday language (Cell 2-E). The treatment group showed a significantly advanced conceptual understanding of photosynthesis in everyday language ($p<0.001$). In addition, students in the treatment group significantly outperformed those in the control group on the questions measuring their understanding of the topic in scientific language (Cell 3-E). These findings are important because they reveal that students in the treatment group demonstrated an improved understanding of the ideas through ordinary

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Table 2. Comparison of mean score between pre-test and post-test for both groups

	Achievement (max)	Group	*n*	Pre-test score (*SD*)	Post-test score (*SD*)	Raw gain	% Gain	*t*	Effect size
	A	B	C	D	E	F	G	H	I
1	Overall score (76)	Treatment	25	11.60 (*5.56*)	29.40 (12.73)	17.80	+23.42	8.70**	1.74
		Control	24	10.79 (*5.31*)	19.29 (8.89)	8.5	+11.18	4.72**	0.96
2	Disaggregate score (39)	Treatment	25	6.76 (*3.60*)	17.80 (6.58)	11.04	+28.31	9.35**	1.86
		Control	24	6.58 (*3.24*)	11.17 (4.87)	4.59	+11.77	4.35**	0.89
3	Aggregate score (37)	Treatment	25	4.84 (*2.61*)	11.60 (6.47)	6.76	+18.27	6.70**	1.34
		Control	24	4.21 (*2.38*)	8.13 (4.27)	3.92	+10.59	4.64**	0.95

**$p<0.001$

language, but also demonstrated a greater ability to use and understand scientific language. What is also significant about these findings is the fact that the smallest difference between students' scores is found on those questions asked using scientific language (aggregate). This result provides further evidence that learning the language of science remains a central challenge in the science learning process.

Analysis 2: Qualitative results

The qualitative component of this research is presented in two parts. First, we described our taxonomical analysis of the types of language used by the students in their interviews. Second, we conducted a comparative analysis of how the experimental and control groups were able to use language to explain scientific phenomena either correctly or incorrectly. To maintain consistent units of examination, we used the speaker's turn taking as our primary unit of analysis.

Types of Language

Our initial analysis yielded three primary categories of analysis: *Use of Science Language, Use of Everyday Language*, and *Use of Hybrid Language*. In those instances coded as *Use of Science Language*, students used scientific terms throughout the course of their turn of talk. We coded students' talk as *Use of Science Language* when students used science terms to describe phenomena in all instances where the scientific concept also had an everyday alternative. For example, when asked why he thought a certain plant would grow, Diego explained, "the plant will get the carbon dioxide that you need to make glucose, and then they'll give the oxygen back, clean" (Diego Armenti-HR-6775, 689). This example was coded as *Use of Science Language* because in each instance in which a scientific idea was expressed, Diego chose to use the scientific terms instead of an everyday alternative. He used the terms "carbon dioxide," "glucose," and "oxygen" to explain the phenomena, whereas other students chose to utilize everyday versions of those words, such as "air that humans and animals breathe out," "sugar," and "good air that plants breathe out." From the time he began his explanation until the time his explanation was completed, he used scientific terms at every possible opportunity.

In contrast, the domain coded as *Use of Everyday Language* describes those instances in which students used everyday descriptions of scientific phenomena throughout their explanation. For example, Dominique explained how sunlight enters the plant, stating, "… the energy pouch. And it takes in the sunlight" (1735, 178). In this example, Dominique was describing the function of a "chloroplast," without using the term in her example. This example is indicative of a pattern that emerged as students used everyday alternatives for scientific terms.

In the third domain, *Use of Hybrid Language*, students switched types of language as they explained the process of photosynthesis. For example, in explaining the concept of photosynthesis, Daniel stated:

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> Plants grow by if you're giving them water, some light and carbon dioxide. The plants grow. They get the water from the roots and some from the leaf. The leaf has pockets to take in sunlight. And then people breathe. And then the plants make this food called glucose, which is sugar and they put carbon dioxide into plants. (Danny Hernandez, HR-235, 585)

This turn of language was coded as *Use of Hybrid Language* because in his explanation Daniel used both the scientific language and the everyday language to explain a scientific idea. He used everyday terms such as "light" instead of "photons," "pockets" instead of "chloroplast," and "sugar" to provide further explanation of the role of glucose. However, in addition to these everyday terms, he also incorporated scientific terms such as "carbon dioxide" and "glucose" in his explanation. We coded this bit of talk as *Use of Hybrid Language* because of the varied use of languages to explain a scientific idea.

Overall, this primary coding of student language provided an indication of how students were able to draw from multiple linguistic resources to describe scientific processes. The analysis that follows provides a detailed analysis of how students used each of these modes of language to explain phenomena.

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Types of science language use. Our analysis of students' use of scientific language reveals five primary patterns. Table 3 illustrates how students in both groups were able to use scientific terms as a tool for identification. Cell 1-A of Table 3 shows how students used an identification mode of language to explain phenomena. When asked for the function of a term or to identify what term matched a particular function, students used scientific terms to generically identify phenomena. For example, one student stated, "Carbon dioxide is what the plants breathe in." A second way students used scientific language was through their treatment of photosynthesis as if it were a recipe. Cell 2-B defines how students used these speech acts to explain photosynthesis as if each scientific term were an ingredient. One student explained, "They take in the photons, the carbon dioxide, and then water. And then they turn into glucose." Another emergent pattern approached anthropomorphism, yet it included explanations in which the students treated the terms as though they were objects to be given and received. Row C of Table 3 provides an example of this, "Humans give plants carbon dioxide." Another emergent pattern of students' conceptually correct use of scientific language involved the scientific terms that vaguely alluded to or did not specify a particular function. For example, Cell 4-C of Table 3 provides an example of one student who explained, "The carbon dioxide helps the boy and the plants." Although the answer is not incorrect, its vague nature and lack of specificity allowed the student to use science terms without having to use them in the appropriate context. The final pattern that emerged was indicative of the ability to use the terms in diverse situations. Cell 5-C provides an example of this type of explanation as one student explained, "Because the dog and the plant are helping each other out because the plant produces oxygen so that the dog will breathe it and then when the dog breathes it out it goes into the plants." Overall,

Table 3. Types of discourse patterns for scientific language used

	Discourse pattern	Description	Example
Cell number	A	B	C
1	Identification	Provides definition or identifies term for given definition	Carbon dioxide is what the plants breathe in.
2	Ingredient	Uses term to complete a "recipe"; of photosynthesis	They take in the photons, the carbon dioxide and then water. And then they turn into glucose.
3	Object	Term is an object given or received	Humans give plants carbon dioxide.
4	Vague	Phrase not associated with function or a general statement	The carbon dioxide helps the boy and the plants.
5	Functional	Term used to describe a phenomenon or answer an open ended question	Because the dog and the plant are helping each other out because the plant produces oxygen so that the dog will breathe it and then when the dog breathes it out it goes into the plants.

students' use of scientific language in both treatment and control groups was similar across each type of correct science answer.

Types of everyday language use. In our analysis of students' use of everyday language, we identified a diverse set of strategies used by students. We analyzed students' use of everyday language in situations in which they described the concept correctly and in instances in which their descriptions were incorrect.

Table 4 provides an overview of the most prevalent patterns of students' everyday descriptors. Overall, we identified seven emergent patterns of everyday language: (1) Students often offered anthropomorphic explanations of scientific terms (Cell 2-B). For example, Diego explained, "And after they put oxygen in the roots, they throw it back out so that humans can breathe it" (HR-2397, 2521). This explanation offers an image of an active plant "throwing" oxygen to humans. (2) Students also used everyday terms to describe the physical descriptors of plant parts (Cell 4-B). John explained how plants have "tiny holes to take (carbon dioxide) in" (HR-2343, 2390). He used the term "tiny hole" to provide a physical description of stomata. (3) Another strategy involved students ascribing ownership to a scientific concept using everyday language in an effort to define it (Cell 3-B). For example, Yanira described carbon dioxide as "the air that the humans breathe out" (HR-1614, 1649). Her explanation described carbon dioxide as something

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Table 4. Types of everyday discourse

	Code name	Code definition
#	A	B
1	Substitution of pronouns for phenomenon	These descriptions involved students substituting pronouns for science phenomenon in every instance where an idea associated with photosynthesis was discussed.
2	Anthropomorphic descriptors	These descriptions involved students using everyday language to provide 'human-like' descriptions of science processes associated with photosynthesis.
3	Ascribing ownership	These descriptions involved students using everyday terms to ascribe ownership to scientific phenomenon in an effort to define them.
4	Everyday functional descriptors	These descriptions involved students' use of everyday terms to describe the functions associated with photosynthesis.
5	Descriptions of locations	These descriptions involved students' use of everyday terms and phrases to describe the locations associated with photosynthesis.
6	Everyday analogy terms	These descriptions involved students' use of everyday language to provide analogies to describe the scientific phenomenon.
7	Miscellaneous	These descriptions involved students using everyday language to describe phenomena in ways that were not repeated by other students.

that belongs to humans and is given to plants. (4) Students also used everyday terms to provide functional descriptions of phenomena. Dominique described how carbon dioxide enters the plant by explaining, "… then the plant takes (carbon dioxide) in through a hole" (HR-1498, 1543). This explanation involves her using everyday terms to describe how carbon dioxide entered the plant. (5) Students also used everyday terms to describe the locations of phenomena. Gustavo explained, "That's where they store the energy and the sugars" (HR-3134, 3183). His explanation of where sugars are stored represents an example of students' use of everyday language in defining the locations of events associated with photosynthesis. (6) Students also reverted to analogies using everyday language to define scientific phenomena. For example, Cassandra used everyday language to describe a chloroplast by saying, "I think that's the thing, that's like, well I think it's like the energy pouch" (HR-8696, 8781). (7) Finally, students often substituted pronouns for scientific terms in their use of everyday language to describe scientific phenomena. For example, Diego explained, "They store it, at first they get the energy and the air, and then they store it inside their roots. So when they need to use it, they get it out" (HR-2720, 2866). Through the use of the pronoun, "it," Diego avoided using the scientific term glucose throughout his explanation.

Types of hybrid language use. An intriguing component of this analysis involved students' use of hybrid language.

In their explanations of the concepts of photosynthesis, students used four types of hybrid phrases to describe scientific phenomena. Cell 3-A of Table 5 illustrates an example of the first type, a *Noun Definitive Clause*—Hybrid description. Each of these hybrid language explanations involved students' use of either the science language or everyday language immediately followed by an additional descriptor using another language. When students used *Noun to Definitive Clause* hybrid descriptions of phenomena, students used the proper scientific noun immediately followed by an everyday language description that provided additional information about the scientific term. For example, one student described carbon dioxide using a *Noun Definitive Clause* pattern by describing it as "the air that humans breathe out." By saying, "carbon dioxide is air that humans breathe out," students were further embedding definitions as they used scientific terms to explain the process of photosynthesis.

A second type of hybrid language, a *Noun to Analogous Clause*—Hybrid description, involved students' use of scientific terms followed by their use of analogies in everyday language to explain certain phenomena. Cell 3-B provides an example of this type of language, where one student explained photons by saying "photon is like sun," or "chloroplast is like little energy pouches."

Table 5. The types of hybrid discourse used in Analysis 1

	Type of hybrid	Definition	Example
Cell	1	2	3
A	Noun to definitive clause	This hybrid description involves the use of a noun to describe the phenomena immediately followed by an additional clause to provide additional explanation.	"Carbon Dioxide is air that humans breathe out."
B	Noun to analogous clause	This hybrid description involves the use of a noun to describe the phenomena immediately followed by an analogy to further explain the phenomena.	"Photons is like sun."
C	Noun to location clause	This hybrid description involves the use of a noun to describe the phenomena followed by a clause to describe the location of the phenomena itself.	Photons from the sun.
D	Noun to taxonomic clause	This hybrid description involves the use of a noun to describe the phenomena immediately followed by a clause to provide additional taxonomic description of the phenomena.	"Glucose, which is a type of sugar." "Glucose, a type of sugar"

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A third type of hybrid language involves the use of the *Noun to Location*—Hybrid pattern of language. In instances in which students used this type of language, they supported their use of a scientific noun by using a phrase in everyday language to describe its location. An example of this pattern occurred when students described photons by referring to them as "photons from the sun."

A fourth type of hybrid description is the *Noun to Taxonomical Clause*—Hybrid description. This hybrid type involves the use of a scientific noun to describe a scientific phenomenon immediately followed by a clause to provide an additional taxonomical description of the phenomenon. For example, one student described glucose by describing it as "glucose, which is a type of sugar," or "glucose, a type of sugar."

Having examined the types of science language used during explanations, we proceeded to examine the frequency of their correct and incorrect use of each of the above modes of language *(Scientific*, *Everyday*, and *Hybrid)*.

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Correct and Incorrect use of Language

Each semi-structured interview was coded for the correct or incorrect use of hybrid, everyday, or scientific terms used in their proper context. For each speech act (considered here to be any uninterrupted stream of language from the student), a code was assigned to both the type of terms used and the accuracy of the student's conceptual understanding. We coded speech acts that included only scientific terms with each term being used correctly as a *science correct concept*. For example, "The humans give plants carbon dioxide and the plants give them oxygen." In this case, the scientific terms "carbon dioxide" and "oxygen" were both used correctly to explain the process of photosynthesis. Speech acts in which only scientific terms were used, but not all were conceptually correct, were coded as a *science incorrect concept*. For example, one student stated, "And then during the day they make photons and chloroplasts, and then they give us oxygen to breathe in, and that's photosynthesis." Because he described plants as making photons and chloroplasts—an incorrect description of photosynthesis, the entire speech act was coded as an occasion of scientific terms used with conceptually incorrect understanding.

Science Language: Correct or incorrect?

Table 6 provides a comparison of each group's relative ability to use science language. Overall, the treatment group used science language correctly (n=148) more than the control group (n=110). On average, the treatment group's use of language (n=7.4 per interview) was greater than that of its control group counterpart (n=6.1 per interview).

To support the idea that students in the treatment group developed an improved understanding of science language, we also documented the frequency of their incorrect use of science language. We found that students in the treatment group were less likely to incorrectly use science language. The students in the treatment group

Table 6. Comparison of uses of correct science language

	Group	Science correct (sum)	Science correct (average)	Science incorrect (sum)	Science incorrect (average)
		A	B	C	D
1	Treatment	148	7.4	84	4.2
2	Control	110	6.1	105	5.8

used science language incorrectly less often (*n*=84) than their control group counterparts (*n*=105). Students from the treatment group made mistakes in their use of science language on an average of 4.2 episodes per interview. In contrast, their control group counterparts mistakenly used science language in 5.8 episodes per interview. Overall, the comparison of students' science talk during the interviews demonstrated that students in the experimental group developed a greater understanding of the science language as indicated by their tendency to use science language correctly more often their peers and by their tendency to use science language incorrectly less often than students in the control group.

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Everyday Language: Correct or incorrect?

We examined students' general use of everyday language strategies to explain scientific phenomena correctly (Table 7). Our analysis revealed that students in the treatment group used everyday language correctly more frequently (*n*=166) than those in the control group (*n*=107). In addition, students in the treatment group were less apt to make erroneous explanations using everyday language (*n*=58) compared to students in the control group (*n*=165). Table 7 provides an overview of students' relative use of everyday language to explain scientific phenomena. What becomes intriguing about this pattern of using science language is that students in the treatment group used non-scientific descriptions accurately to describe scientific phenomena.

Given the fact that our coding of the students' interviews was conducted blindly with respect to the students' group assignment, this finding further supports the idea

Table 7. Frequency of correct/incorrect everyday language

	Group	Everyday correct (sum)	Everyday correct (average)	Everyday incorrect (sum)	Everyday incorrect (average)
		A	B	C	D
1	Treatment	166	5.9	58	2.9
2	Control	107	2.9	165	9.16

that students taught using our approach were both less apt to use scientific language incorrectly and were more apt to use everyday language correctly. Such a perspective provides support to the idea that students developed a rich understanding of the idea through everyday language (Cell 1-C).

Hybrid Language: Correct or incorrect?

In addition to our analysis of the types of hybrid language, we analyzed how each group used hybrid language to answer questions correctly or incorrectly (see Table 8). Cell 1-A demonstrates that students in the treatment group used hybrid language correctly in explanations more often (n=73) than their control group counterparts (n=63). In contrast, the control group students used hybrid language incorrectly more often (n=46) than their treatment group counterparts (n=28). This finding is consistent with the other results of this study that demonstrate that students were able to use scientific language correctly more often than the control group and were less likely to use hybrid language incorrectly. Given the fact that these results document instances in which students blend types of language, it becomes clear that the students in the treatment group demonstrate a superior ability to explain scientific ideas even when scientific language is blended with everyday descriptors.

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Conclusions

The results of this study provide some intriguing insights regarding our theoretical argument concerning the impact of *Disaggregate Instruction* as it relates to science learning. Our study suggests that teaching science content without using dense, scientific language does affect both students' development of conceptual scientific understanding and their ability to use scientific language correctly. Both the qualitative and the quantitative results from this research study indicate that students who were taught in this manner not only developed an improved conceptual understanding but were also better equipped to use scientific language in explaining scientific ideas. The treatment group's ability to understand, speak, and write about scientific phenomena indicates the dynamic impact of taking a disaggregate approach to science teaching. Although students in the treatment group demonstrated an improved ability to use scientific language, the fact that all students scored lowest on

Table 8. Frequency of correct/incorrect hybrid language

		Hybrid correct (sum)	Hybrid correct (average)	Hybrid incorrect (sum)	Hybrid incorrect (average)
	Group	A	B	C	D
1	Treatment	73	3.8	28	1.4
2	Control	63	3.5	46	2.5

questions asked using scientific language lends further evidence to the idea that the acquisition of the academic language of science remains one of the most difficult aspects of students' science learning.

Given the inherent difficulty of learning scientific language, disaggregating science into conceptual and linguistic components enables researchers to understand the impact of academic language learning in students' ability to understand material. The findings presented here draw attention to the need to examine science teaching and learning from a perspective that examines student learning across conceptual and linguistic domains.

Along those same lines, our analysis of the impact of the Disaggregate Instruction approach in the web-based environment has the potential to contribute to how science educators think about science teaching. If students are struggling to acquire the language of science, how can science education continue to neglect academic language instruction? Although we are not proposing the *Disaggregate Instruction* as the sole approach to teaching both content and language, we do suggest that teachers consider innovative ways to develop disaggregated instruction which first introduces students to ideas in everyday language that will build bridges to their scientific language acquisition. Future research should investigate how teachers implement the disaggregate approach in their science teaching and how their use of this approach impacts students' science learning.

If science educators begin to conceptualize the teaching and learning of science through a lens that seeks to identify the conceptual continuity between students' everyday language strategies and scientific language, we may improve science learning for all students. More importantly, if we are able to identify the continuity that exists between students' understanding, as expressed through everyday or non-scientific language and its scientific counterpart, we may be able to design instruction that can successfully utilize students' valuable everyday knowledge as a resource in their academic language acquisition process. If teacher education programs improve their ability to prepare teachers to understand the impact of language acquisition and to become aware of the relative levels of continuity between students' everyday expressions of understanding and their scientific counterparts, we may be able to improve how students understand, read, write, and talk about science.

In addition to the teaching and learning dimensions of taking a language approach to teaching, teaching using this method may have a positive impact on a student's discursive identity. Although our analysis here did not provide us with an opportunity to examine the impact of this teaching method on students' discursive identity, we hope to address this issue in future research.

The use of language is inherently connected to students' identity; however, teaching in the fashion presented here creates norms for instruction that dictate how students are to use language. A subtle change of that nature may have an impact on students' identity because the issue of social agency in presenting who you are through your use of language is decreased because the teacher has emphasized a preferred language that is foreign to all students. If students are uncomfortable with

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using science language because of its symbolic representation of "who" they are, then defining what language is to be used can impact the social dimension of language selection. Such an approach is akin to a Spanish immersion class, where all students are allowed to stumble through the use of Spanish on the pathway to fluency. In this same vein, taking an approach to science that teaches the ideas of science first and then requests a "science immersion" component of instruction may decrease the social impact of using language as an identity cue. In the end, this research provides us some primary insights into the impact of taking a content first approach to science teaching and its impact on student learning.

A final obstacle of this work involves the fundamental challenge to what teachers recognize as "correct" science. We do not intend to challenge what counts as correct, yet we do want teachers to reconsider how they assist students in proceeding towards these correct answers. Disaggregate Instruction begins by assuming that students can be introduced to correct science ideas through a genre of language that is not traditionally a component of science classrooms. This assumption is rooted in our conviction that this approach will make science more accessible and it will reduce the cognitive load of having to learn new science concepts and new science language simultaneously. Ultimately, we are challenging teachers and teacher educators to develop classroom instruction that carefully uses students' language resources to guide them on their pathway to science fluency.

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Notes

1. This is a pseudonym that was used to protect and maintain the anonymity of the school and the children.
2. All the names of students that are used in the interview are pseudonyms that are used to protect the privacy of the students.

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