CREATING LANGUAGE-RICH SCIENCE CLASSROOMS FOR ENGLISH LANGUAGE LEARNERS

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Abstract: In the DISCUSS (Dialogic Inquiry for Socioscientific and Conceptual Understanding in School Science) research project, a Socioscientific Issues (SSI)-based curriculum is developed and implemented in sixth-grade science classrooms with predominantly English language learners (ELLs) in Houston, Texas. A four-week space unit is designed in collaboration with researchers and science teachers to improve students' science content knowledge, reasoning and argumentation, and academic language through dialogic inquiry of a central question: *Should the U.S. government increase or decrease funding for space exploration?* The unique features of the curriculum include the expansion of 5E instructional model to the 7E model for ELLs, the use of classroom discussions to facilitate reasoning and argumentation, and the integration of effective literacy strategies in lessons. Students investigate four-domain issues—technology, environment, economy, and public policy—associated with space exploration by reading argument texts, engaging in teacher-led whole class discussions and peer-led small-group discussions, and hands-on group work. At the end of the unit, students write an individual decision letter to address the central question. The multidisciplinary DISCUSS curriculum is promising to help teachers create language-rich science classrooms and promote science learning, reasoning and argumentation, and academic language development of all students especially ELLs.

Keywords: dialogic inquiry, socioscientific issues, space exploration, reasoning and argumentation, English language learners

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Acknowledgements

The DISCUSS research group would like to thank participating teachers, students, and parents. We appreciate Jennifer Donze's assistance in teacher training and data collection. We also acknowledge the funding support from the University of Houston.

English language learners (ELLs) now comprise 11% of the U.S. school-age population (National Center for Education Statistics, 2011). In Houston, Texas ELLs make up approximately 30-40% of public school students (Houston Independent School District, 2015). The persistent achievement gap between ELLs and their native English-speaking peers in reading and science (NCES, 2011) has posed a serious challenge for literacy and science educators. ELLs need to develop science conceptual knowledge while developing linguistic skills. However, instruction of content and language are typically disjointed, which results in poor performance and low engagement in science learning for ELLs (Bailey, Butler, LaFramenta, & Ong, 2004). The DISCUSS (Dialogic Inquiry for Socioscientific and Conceptual Understanding in School Science) project aims to address the gap by engaging middle school students in extended inquiry dialogue about relevant socioscientific issues.

The use of dialogic inquiry (Alexander, 2008; Wells, 1999) in science and content area literacy is important because it "centers around strategic use of classroom talk to support student learning" (Reznitskaya & Wilkinson, 2015, p. 221). The DISCUSS curriculum adopts Collaborative Reasoning (CR), a dialogic approach to small group discussion that has been proved to be successful in promoting ELLs' reasoning, thinking, and language development (Zhang, Anderson, & Nguyen-Jahiel, 2013). In CR, students read a text that raises a dilemma or unresolved issue. Students then gather in groups of five to eight to deliberate on the Big Question (e.g., *Are zoos good places for animals?*) raised by the text. Students present their positions on the Big Question, support the positions with reasons and evidence, carefully listen, evaluate, respond to one another's arguments, and challenge each other when they disagree. CR calls for critical and reflective thinking, and features open participation (Clark, Anderson, Kuo, Kim, Archodidou & Nguyen-Jahiel, 2003), in which students speak freely without being nominated by the teacher. Students are encouraged to manage all aspects of discussion as independently as possible. Teachers facilitate the discussion from the side and provide scaffolding when needed.

Engaging students in extended inquiry dialogue about socioscientific issues (SSI) is a promising means promote student science content knowledge and academic language especially for ELLs. SSIs are controversial social issues with conceptual or procedural links to science (Sadler, 2004). Research evidence suggests that the use of SSI curriculum improves student understanding of science concepts (e.g., Kinslow et .al., 2017; Sadler, Romine, & Topcu, 2016), decision making skills (Gutierez, 2015; Zhang et al., 2016), and academic vocabulary use in oral discourse (Ma et. al., 2017). The space exploration issue was chosen in the DISCUSS project based on four criteria: a) relevance and interest to students, b) science content behind the issue, c) accessible ethical tensions, and d) alignment with Texas Essential Knowledge and Skills (TEKS). Partnering with district science leadership teams and teachers, the DISCUSS research team has developed the unit on space exploration featuring small-group and whole-class inquiry dialogue that cultivated critical and reflective thinking, deeper understanding of science concepts, and extended language use to solve complex and socially relevant science problems.

Overview of Space Exploration Unit

The unit was designed for students to address a contestable and relevant central question: *Should the U.S. government increase or decrease the funding for space exploration?* Students role-play being members of the Space Exploration Advisory Council, commissioned by the Office of Space Exploration Agency to make a recommendation regarding the government's space exploration budget. Students are introduced to the issue through an introductory packet and newsletter. The introductory packet sets up the scenario and students read a letter from the Office of Space Exploration Agency which commission the Council to investigate the issue and make the recommendation. The newsletter presents snapshots of the budget issue as well as life stories about the positive and negative impact of space exploration.

The unit was designed to take place with a four-week period with 20 lessons. Science content covered space science aligned with TEKs. To help students consider the multifaceted socioscientific issues, four relevant areas associated with space exploration should be considered when addressing the central question: technology, economy, environment, and public policy. Students learn how space exploration affects technological innovation, aspects of economy such as businesses, job opportunities and government income, earth and space environment, and how different groups of citizens influence public policy related to space exploration. Table 1 displays the weekly unit layout that integrates science content and socioscientific issues.

Table 1. Space Exploration Unit Layout

Week	Science Content Coverage	Socioscientific Issues and Activities
• Week 1: Establishing background	• Introduction to space exploration issues • History of space exploration	• Setting up a scenario • Considering the central question • Space exploration and technology
• Week 2: Developing expertise I	• Solar system: scale of relative distance • Scale of relative size of plants • Characteristics of planets	• Space exploration and economy
• Week 3: Developing expertise II	• Gravity • Galilean moons, meteors, meteorites, asteroids, comets	• Space exploration and (Earth and • Space) environment
• Week 4: Engineering design and decision making	• Introduction to rocketry • Rocket launch and redesign	• Space exploration and public policy • Reconsidering the central question • Writing an individual decision letter

The following sections describe the core literacy strategies and how they are applied to SSI and science lessons in the DISCUSS curriculum.

Text-Based Collaborative Reasoning Discussions

Four argument texts associated with space exploration issues—technology, environment, economy, and public policy—were written to provide students with essential arguments and opposing. Figure 1 illustrates the structure of a sample argument text. Throughout the argument texts, clear headings are used to highlight each side of the argument; key science content-specific vocabulary (e.g., *emissions, degradation*) and general academic vocabulary (e.g., *insulate, resilience*) are defined, and interesting and relevant background information as well as visual representations (e.g., graphs and pictures) are provided to facilitate text comprehension (see Figure 1).

Each week, students read one argument text and engage in small-group discussions and essay writing considering different perspectives. After reading the text, the class is divided into groups of five to seven members to engage in Collaborative Reasoning discussions about the Big Question listed below.

Week 1 – Technology: "*Would increasing or decreasing funding for space exploration be good for technological innovation?*"

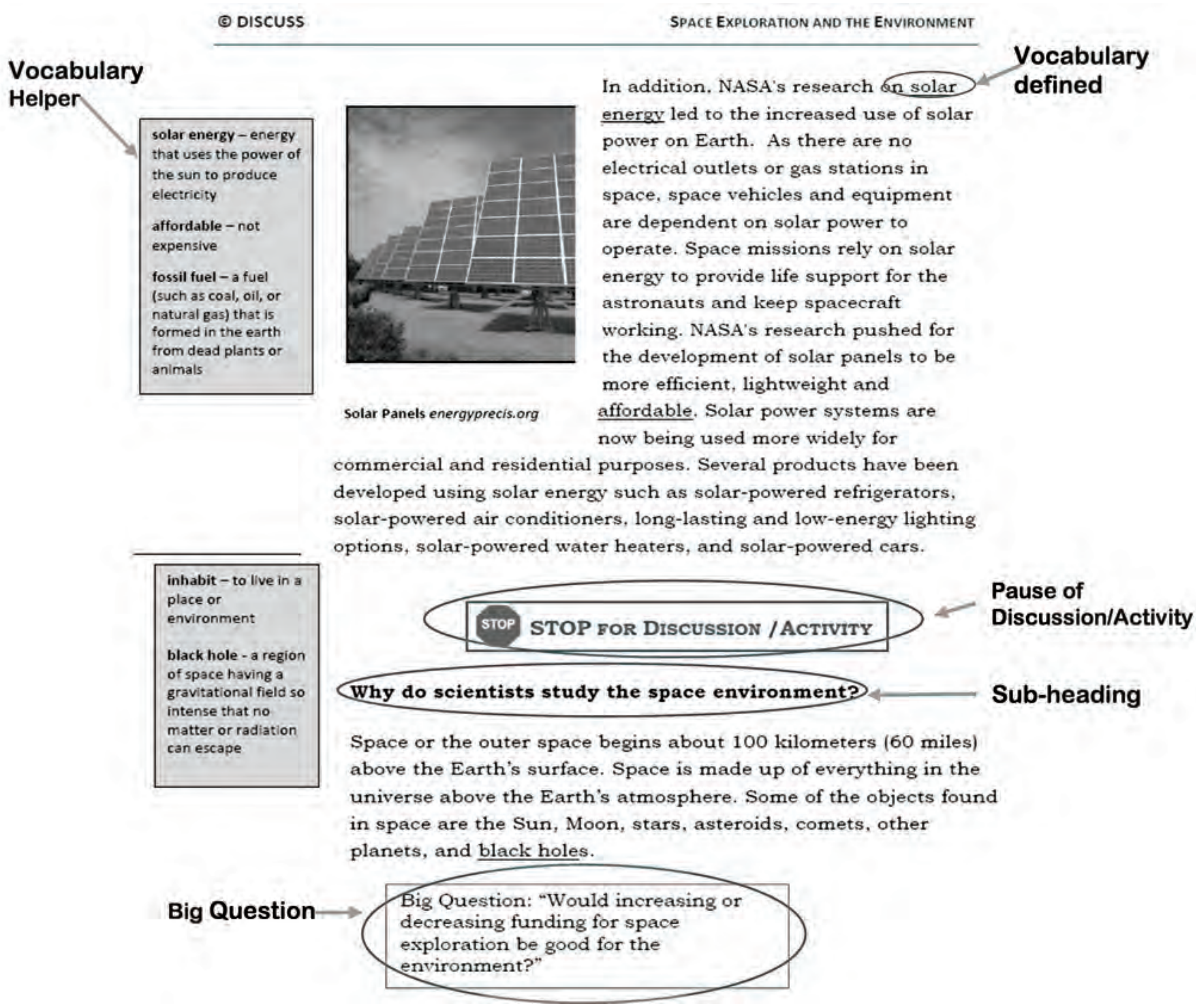
Week 2 – Economy: "*Would increasing or decreasing funding for space exploration be good for the economy of the United States?*"

Week 3 – Environment: "*Would increasing or decreasing funding for space exploration be good for the environment?*"

Week 4 – Public Policy: "*Would increasing or decreasing funding for space exploration the best public policy for the American people?*"

To start the CR discussion, teachers first set up the ground norms, then pose the Big Question, and then invite open-participation. Students are encouraged to manage their own discussion and express their positions/claims, provide supporting evidence, challenge one another, and consider alternative perspectives. The discussion typically lasts ten to fifteen minutes. Teachers scaffolding moves include prompting for position and reasons (e.g., *What do you think? What are your reasons?*), modeling and thinking out loud, asking for clarification (e.g., *What do you mean by…?*), challenging (e.g., *Some people might disagree with you because…; Aren't you making an assumption that might not be true?*), stepping and reminding (e.g., *Let's listen to each other and not talk over one*

Figure 1. Structure of a sample argument text.



another), encouraging (e.g., *That was a good reason*), fostering independence (e.g., *What do you think about John's argument?*), summing up and re-focusing (e.g., *So far you have given two reasons. The first reason is.... The second reason is...*), and debriefing (i.e., reflections on the strengths and weaknesses of the discussion) (Clark et al., 2003).

After the CR discussion, each group is asked to summarize their main arguments and create an argument diagram. The students write their claim, evidence, and reasoning (CER) on a large post-it chart. Students are encouraged to write arguments for both sides of the issue, *in favor of increasing* and *in favor of decreasing* columns of the chart. Teachers are provided an argument outline illustrating main arguments on both sides. After completing the argument diagram, students individually write a short essay to address the Big Question. Students are again encouraged to use the CER framework (McNeill & Krajcik, 2011) in their argument writing.

On the last two days of the unit, students review the key arguments on all four domains and evaluate the strengths and weaknesses of the arguments for each domain. Students then engage in another CR discussion about the central question. After the discussion, students write an individual decision letter addressed to the Space Exploration Agency expressing their recommendation on whether to increase or decrease funding for space exploration.

Other Research-Based Literacy Strategies for ELLs

The DISCUSS curriculum adopted the Sheltered Instruction Observation Protocol (SIOP) model (Short & Echevarria, 1999) to develop ELLs' domain-specific content knowledge and language proficiency. Two types of instructional objectives—content and language—are established in every lesson. Other research-based literacy strategies include word learning strategies, visuals and graphic organizers, comprehension strategies, and argumentative essay writing.

First, students are repeatedly exposed to selected academic vocabulary words in rich and varied contexts (such as argument texts, PowerPoints, activities). Teachers explicitly draw student attention to the word parts or morphology (e.g., astronaut, astronomy, and astronomical share the same root, astro) to infer the meanings of new words. Second, teachers use visuals to explain the meanings of new concepts or vocabulary (e.g., word map) and use graphic organizers (e.g., argument diagram) to facilitate understanding and producing arguments. Third, the comprehension strategies are used at three stages: before reading (e.g., making a prediction), during reading (e.g., asking questions, making connections), and after reading (e.g., summarizing, evaluating, and questioning the author). Fourth, students have multiple opportunities to practice argumentative writing. Each week students engage in quick writing and responding to the Big Question. At the end of the unit, students write an individual decision letter.

7E Model and Sample Lessons

A modified version of the 7E model developed by the Center for Research on the Educational Achievement and Teaching of English Language Learners' (CREATE) was used in this study to design the set of 20 lessons. The CREATE's 7E lesson model was based on Biological Science Curriculum Study's (BSCS) 5E model and integrated methods that develop science knowledge and academic language. Traditional 5E model in science teaching includes Engage, Explore, Explain, Elaborate, and Evaluate. To address the needs of background knowledge and academic vocabulary for ELLs, our version of the 7E model introduces "Elicit" and "Establish" in the lesson model. In the DISCUSS 7E model, the lesson begins with Elicit then Engage, Establish, Explore, Explain, Elaborate, and Evaluate. During Elicit, the teacher prompts for prior knowledge, identify misconceptions in student understanding, and introduce content and language objectives. Engage uses various methods to increase student interest and connects the lesson objectives with students' lived experiences, home life, and culture. Establish provides the relevant and necessary background information and vocabulary knowledge for students to understand the lesson. This may include preteaching science concepts and providing explicit instruction of academic vocabulary and word learning strategies. Explore gives students opportunities to design an experiment, collect data, and interpret results. Explain is when students share their hands-on experiences during explore. They present and explain findings using claims, evidence, reasoning and the teacher guides and clarifies as needed. Elaborate involves students using new vocabulary to apply or extend concepts to build on the new knowledge. Evaluate can consist of open-ended questions, class discussions, assessments, or other ways that students will demonstrate understanding.

Table 2 defines 7E model and illustrates how we applied our 7E model in a sample science lesson and a sample SSI lesson from the unit. The topic of the science lesson is scale of relative size of planets. Students create a scale model of the planets of the solar system with modeling clay and explore why Pluto is no longer considered a planet in the solar system. The topic of the SSI lesson is to investigate positive and negative impact of space exploration on technological innovation.

The DISCUSS Curriculum in Action

The DISCUSS curriculum was implemented in three sixth-grade science classrooms serving predominantly ELLs with diverse language backgrounds in Houston, Texas. One class served Spanish-English bilingual students. Two other classes served general education students. Based on our classroom observation, the three teachers followed 7E lesson plans in content delivery and used a core group of aforementioned literacy strategies throughout the unit. Sometimes the teachers adjusted the lesson plans to meet the needs of their students. For example, the Spanish-English bilingual science teacher frequently used code-switch and cross-lingual strategies to explain academic concepts and vocabulary. The teachers perceived the unit being student centered, and engaging, valued vocabulary enrichment and ample opportunities for their students to reason and justify decisions through extended dialogue. Regarding the opinion of integrating socio-scientific issues in science instruction, the bilingual teacher reflected: "It is a great thing, just getting the kids to understand that, because especially these young people, they have little connection with society... if you understand what are the political situations... it is not something that is talked at home, and they hear it for the first time here, so someone has to expose it to them."

The biggest challenge we encountered during the curriculum implementation was how to make the science teachers better embrace the dialogic strategies given the time constraints. The teachers expressed concerns about pacing, meeting state standards and insufficient time for reading and discussion. Our future direction would be to collaborate with both language arts and science teachers so that the reading and discussion activities can be implemented during the language arts periods and the science lessons can focus more on science content knowledge and hands-

Table 2. Illustration of 7E Model and Science and SSI Lesson Samples

Stage	Description	Science Lesson Activities	SSI Lesson Activities
ELICIT	• Elicit prior knowledge regarding content • Identify misconceptions in student understanding • Introduce content objectives • Introduce language objectives	• Ask students what they know or remember about the planets in our solar system • Introduce content and language objectives via a PowerPoint slide • Ask students to read vocabulary words aloud to the whole class	• Introduce content and language objectives via a PowerPoint slide • Elicit students' prior knowledge about how space program has impacted everyday life
ENGAGE	• Generate interest and curiosity in topic of the lesson • Raise questions and/or students raise questions regarding topic • Connect lesson objectives with students' lived experiences, home life, culture, etc.	• Ask students if the sun was the size of a basketball, how big the other planets will be in comparison • Write down student claims on the whiteboard, or a place where students can see their responses • Ask students if they have ever talked about the solar system, the sun or planets with their families, visited an observatory, etc.	• Show a set of eight pictures of invented products on and ask students which products are invented by NASA's space exploration projects • Have students name each of items first and discuss why they believe the product is invented by NASA
ESTABLISH	• Provide relevant and necessary background information for students to participate in the lesson topic • Provide explicit instruction of academic vocabulary and word learning strategies	• Preteach science concepts by asking students what they know about scale, proportion, model and scale factor • Provide definitions and examples of each term • Have students read a text that will provide guidance on the concept of a scale model • Have students add terms to their science glossary	• Preteach the target words listed on the Language Objectives • Use a concept map for the types of technology • Ask students to come up with all the words related to transportation, medical, communication, agricultural, and environmental technology
EXPLORE	• Give students opportunity to work together without direct instruction • Allow students to test hypotheses, conduct hands-on investigations on key concepts and engage in discussions with peers • Facilitate student exploration by asking questions and prompting for authentic scientific experimentation	• Have students work in small groups of three to four to create a scale model of the planets of the solar system with modeling clay using the reference of the sun as the size of a basketball • Have students reference previous day's handout on the sizes of the planets in our solar system • Have students discuss with teammates to decide on the size and prepare to present their evidence and reasoning to whole class	• [BEFORE reading] Prediction: Ask students to read the subtitles and browse pictures and predict the topic • [DURING reading] Have students read the assigned sections of text • [AFTER reading] Ask students to summarize the main ideas and identify CER (Claim-Evidence-Reasoning) elements of the argument
EXPLAIN	• Allow students to present and explain concept in their own words using Claims, Evidence, and Reasoning • Foster discussion in small group and/or whole group • Prompt students to listen and comprehend others' ideas • Facilitate and guide towards accurate understandings	• Allow students to present their model to the class • Have students use evidence and reasoning to explain their claim on their scale model of the solar system • Ensure groups listen to other groups, and ask questions of each other to encourage argumentation • Guide students to understand how they used proportions to generate a scaled model of the solar system • Present key model	• Divide students into small groups of five to seven • Set ground norms and rules for CR discussions • Have each small group discuss the Big Question: "Would increasing or decreasing funding for space exploration be good for the technological innovation?" • Guide student to share their claims, provide supporting
ELABORATE	• Help students use new vocabulary and apply concepts and skills in new but similar situations • Prompt students to use alternative explanations and existing evidence to explore new situations • Encourage students to use previous information to ask questions and propose new solutions	• Remind students that they did not include Pluto in their model • Have students apply their knowledge of proportions to add Pluto to their model • Ask why Pluto is no longer considered a planet and allow students to share thoughts • Show a video that explains the controversy behind Pluto's classification as a dwarf planet; have students write in their science notebooks the three characteristics of a planet • Teview the three characteristics of a planet; have students discuss why Pluto is no longer classified as a planet	• Ask each group to summarize the main arguments in the CR discussion. Use the prompt *"What are your claim, evidence, and reasoning in favor of increasing and decreasing funding on space exploration for technological innovation?"*
EVALUATE	• Assess students' content and language knowledge and skills • Assess students' ability to apply new concepts • Allow students to receive feedback and consider their own learning • Have students use empirical evidence and existing scientific knowledge to reason claims and generate new questions	• Have students work in same teams to determine the proportion of dwarf planets Ceres, Haumea, Makemake, and/or Eris if the sun is the size of a basketball; have groups use CER to explain their conclusion • Have students complete a quick write in their science notebooks: How did you determine the size of the dwarf planets? Encourage students to use claims, evidence, and reasoning in their writing	• Have students write a short paragraph about their argument regarding the Big Question: *"Would increasing or decreasing funding for space exploration be good for technological innovation?"* • Encourage students to use CER strategies in their argumentative writing

on inquiries. The pacing issue, however, cannot explain alone the teachers' difficulty in fostering inquiry dialogue. To make the science classrooms truly dialogic, teachers need to release more responsibility for the students to lead the discussions, effectively facilitate rich classroom dialogue, and encourage students to challenge each other's evidence, assumptions, and reasoning. Teachers also need to promote students to relate their ideas to what has been said by others, and engage students in critical and collaborative co-construction of ideas and exploratory talk (Mercer, 1996).

Despite the challenges, we see the promise of the curriculum in promoting teaching practices that broaden ways of student talking and thinking. Students liked the hands-on inquiries, small-group activities, and content-focused and discussions that are centered around the decision making regarding NASA's budget. Concerning what students liked about the unit, a student commented in the student survey that "it made me think better, read better, and work harder." Another student reflected, "Making big decisions makes me feel important." Students thought the unit was different from their regular science lessons because "it had way more discussion and required a lot of thinking."

The next step for us is to analyze the videotaped lessons and pre- and post-intervention assessments to fully understand how teacher practices impact student learning. We hope to generate insights that can help teachers to create intellectually stimulating, personally engaging language-rich science classrooms to better serve the academic needs of students especially ELLs.

Acknowledgements

The DISCUSS research group would like to thank participating teachers, students, and parents. We appreciate Jennifer Donze's assistance in teacher training and data collection. We also acknowledge the funding support from the University of Houston.

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