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Abstract

The use of higher level questioning by high school students is known to promote problem solving during group discussions. However, the research on questioning patterns in collaborative groups is mostly restricted to elementary and middle schools. Not enough is known about questioning patterns employed by students during group discussions in socioeconomically diverse high schools. The purpose of this grounded theory study was to fill in that gap. The research's goals were to record the questioning patterns used during group discussions of environmental science topics, find how often students utilize higher level thinking questions and what the nature of those questions is. The research took four days and showed that the percentage of higher level questions used by the experimental group in Day 4 was significantly higher (85%) in comparison to 65% in Day 1.

Keywords: collaborative learning, socioeconomically diverse high schools, questioning techniques, critical thinking and high level thinking questions

The use of higher level questioning is well known to promote problem solving during group discussions because the level of the thinking that occurs in the classroom is the outcome of the level of questions asked by both students and teachers (King, 1991; King 1995; Zohar, Degani & Vaaknin, 2001). Regrettably, the research showed that most students do not do well on tasks that require critical thinking skills (Bailin, 2002). A successful execution of this type of tasks requires student exposure to learning techniques that incorporate appropriate higher reasoning and critical thinking strategies (Dam & Valman, 2004). In addition, students have a better chance to succeed on tasks that require critical thinking when they practice and utilize critical thinking in several contexts (as cited in Zoller & Pushkin, 2007). However, the research on discourse patterns in collaborative groups is mostly restricted to elementary and middle school students, and most findings related to the usage of higher level questioning were established in that limited context. Not enough is known about the questioning patterns employed by students during group discussions in socioeconomically diverse high schools. One of the few studies conducted with underrepresented students in a high school science classroom showed that those students were given few opportunities to contribute to discourse (Yerrick & Gilbert, 2011). The same study, which was an ethnographic study, illustrated that the students were not allowed to express their own opinions but rather were permitted to use other people's scientific views. Another study, (Anyon, 1980), showed that students in the working-class school's science class may spend most of their time just copying their teacher's notes from the board. Even when they did experiment, the teacher often demonstrated the experiment for the students and wrote on the board their "found" data.

Many researchers argued that educational experience and curriculum knowledge offered to students vary in different social classes. For example, in the elite school's science classrooms students may be required to generate their hypothesis by manipulating the variables, conducting experiments and providing elaborations and justifications about their found data. Unfortunately, this may not hold true in poor, urban, or socioeconomically diverse schools. Resnick (1987) argued in the past that fostering competent thinkers was a target for only a small group of elite students. The majority of students did not have the luxury of benefiting from the fruits of the higher order thinking and meaning, thus being denied equal educational opportunities (Zohar & Dori, 2003). The National Science Standards highlighted the fact that higher order thinking skills should be offered to all students, which hopefully would narrow the gap between low and high achieving students (Hollweg & Hill, 2003; NRC, 1996). In particular, it is not evident if students in urban or socioeconomically diverse high schools make intensive use of thought-provoking questions. Additionally, it is not clear how asking thought-provoking questions impacts urban or socioeconomically diverse high school students' problem solving skills.

Purpose

The purpose of this grounded theory study was to investigate and analyze the questioning patterns used in student discourse during collaborative group discussions. The grounded theory was chosen as the method of the qualitative research in this study due to data collection, analysis and a subsequent formation of the theoretical model (Glaser & Strauss, 1967). Data used for this grounded theory study included students' writings, video and audio analysis, field notes and observations. The participants of this study were freshmen from a socioeconomically diverse high school located in the East Coast studying Environmental Science.

The main research question and secondary questions

Main question

What questioning patterns are displayed by students during group discussions in an environmental science class in a socioeconomically diverse high school?

Secondary questions

- What is the nature of questions raised during the discussion?
- How often and under what conditions do socioeconomically diverse high school students utilize higher level thinking questions in their discourse during group work?
- How are these questions taken up by students' peers?
- When higher level thinking questions are used, do they lead to better scientific explanation?

Significance of the Study

As many researchers and educational advocates stated, (Bell, 2010; Bybee & Fuchs, 2006; Hofstein & Lunetta, 2004; Silva, 2009) students need significantly different educational skills today than the ones needed in the past century. If the student could read and write in the 20th century, he/she would be considered a literate person. This is not the case anymore. To be successful in the 21st century, students need certain essential skills like critical thinking and problem solving skills as well as fluency in technology and data analysis. Therefore, by cultivating critical thinking skills among students, educators can prepare students to become 'competent citizens', which will allow them to make their own critical contributions to the democratic and modern society (Dam & Volman, 2004). Additionally, because of the technological advancements, the demand for blue collar workers has decreased whereas the need for highly urbane, literate workers has increased (Zohar & Vaaknin, 2001). This observation was supported by Levy and Murnane (2005) who have indicated that the routine skills are currently being replaced by the computers. These statements lead to the following conclusion about the academic learning: it is imperative not only to improve students' achievement but also to increase their scientific literacy and critical thinking skills. Scientifically literate citizens can read and analyze scientific articles written in popular scientific journals and magazines. Their scientific literacy helps them to understand complex, controversial problems, which either have no solution at all or have more than one solution. In order to reach to this cognitive level, students need to have higher order cognitive skills.

As it became apparent from the above-mentioned studies and reports, the students in the United States should be prepared to be part of the 21st century workforce. This goal can be achieved by providing our students with a vigorous curriculum, by fostering students' critical thinking skills, which in turn will allow students to solve semi-structured problems and become better decision makers. This approach will assist in the goal of generating higher levels of scientific and technological literacy among US students (Bybee & Fuchs, 2006). Although the preparation for the 21st century workforce seems to be a worthy undertaking with promising outcomes, some critiques find its stated goals universal rather than specific to our current environment. For example, Silva (2009) argued that critical/creative thinking and analytical skills were not new for humankind. They were propagated during the Greek civilization (Socrates), were highlighted in the 20th century (Dewey). Silva also referenced other critiques who stated that assessing those skills is challenging due to difficulties in applying valid and cost-effective measurements. In summary, Silva's viewpoint was labeling these skills as 21st century skills is misleading since they are not new skills, but rather are newly important.

Students learn the material by doing it (Dewey, 1938). This is even more applicable to learning science when children learn science by doing science. The PBL (Project-Based Learning) which is a relatively innovative pedagogical approach for enhancing students' 21st century skills, opens wide horizons for students by letting them to learn independently. Not surprisingly, the main goal of science reform was a switch from lower-order cognitive skills to the higher-order cognitive skills (Tal et al, 2001). Consequently, some modern testing procedures use more tasks that require critical thinking skills. For example, some recent End of Course Biology examinations contain a section where students are asked to design an experiment using their scientific thinking and reasoning skills.

This study on questioning patterns during group discussions in Environmental Science class will provide researchers and educators with valuable information to help them to better understand the inner workings of group discussions in socioeconomically diverse high schools. This may lead to the development of enhanced educational methods and tools which can better prepare students for this globalized and hyper-competitive world. In addition, the results of this study should be applicable to other subjects such as math, language art, social study, etc. In other words, any questioning pattern and strategy that was successfully utilized in the course of this study should be valid for other fields too, not only in science education.

Theoretical Framework

Collaborative learning groups were the subject of rigorous research for more than four decades. Numerous studies in this field of educational research have examined both benefits and disadvantages of collaboration in groups, its effects on students' achievement and motivation, various teaching strategies that promote collaboration, and students' interactional and discourse patterns in collaborative groups (Dennen & Hoadley, 2013; Johnson & Johnson, 1989; King, 1992; Slavin, 1991; Webb, 1984; Zhang, 2013). These researchers also highlighted that students learn more via collaborative learning than via traditional, teacher-centered approaches. The interactions with others help learners to construct, revise and interpret others' ideas and viewpoints, something that they could not perform in isolation (Webb & Mastergeorge, 2003). Moreover, Vygotsky (1978) considered language as a major psychological and cultural tool which helps learners to formulate new understandings of learning. The results of these studies supported the notion that collaborative learning leads to better educational outcomes.

Although the early research demonstrated the overall positive impact of collaborative learning on students' educational outcomes, it was also apparent that collaboration itself without any supportive framework could not ensure success. Therefore, it has become essential to study group interactions and student behaviors that promote learning in collaborative groups. It was determined that active participation, such as giving and receiving help, sharing knowledge, engaging in reciprocal questioning, using well-formed reasoning constructs played an important role in successful collaborative learning. Research showed that students learn not only when they receive help but they learn even more when they provide elaborated explanations to their peer who seek help (Webb et al, 2002). In contrast, receiving no elaborated help, such as when getting just the final answer, negatively relates to students' achievement (Webb, 1989). As it is evident from the above, the constructivist-style teaching where students take ownership and teach their peers may benefit not only the students who receive help but also those students who are promoting cognitive elaborations. These research findings align well with Roman philosopher Seneca's ideas who acknowledged, "Qui Docet Discet," meaning when you teach you learn twice.

The appropriate use of thought-provoking, high-level questions during discussions can greatly help in shaping a discourse that can lead to better collaboration. This study will thoroughly examine the questioning patterns that occur during group discussions in socioeconomically diverse high school.

This study draws upon several theoretical perspectives that provide a conceptual framework that rationalizes why collaboration may promote learning. Following Piaget's socio-constructive perspective (DeLisi & Golbeck, 1999), peer interactions in collaborative groups can create cognitive conflict and, as a result, disrupt equilibrium between assimilation and accommodation. This in turn may trigger modifications of learner's cognitive system. Therefore, reflecting on peer reactions and perspectives provides the necessary means to a learner for reviewing and refining his/her cognitive system. One of the central concepts in the Vygotskian socio-cultural perspective (Hogan & Tudge, 1999) was the notion that shared problem solving during which children learn from more skilled partners, results in higher cognitive functions. For that reason, children's collaboration with their more skilled peers can cause cognitive growth. Less skilled individuals can benefit by getting explanations which help them to clarify and organize their own thinking (Webb & Mastergeorge, 2003). Cognitive elaboration perspective focuses on cognitive restructuring (O'Donnell, 2006). According to this approach, interaction with others may cause learners to restructure their knowledge and understanding.

To recapitulate, collaborative learning is more effective than more traditional learning approaches. However, collaboration itself does not guarantee success unless it happens in a supportive framework. It was shown that the appropriate use of higher level, thought-provoking questions during discussions can lead to better collaboration (Chin & Osborne, 2010; Dori & Herscovitz, 1999; Wells & Arauz, 2006).

Asking questions, especially when students pose questions, is considered a great educational vehicle for all subject areas, specifically in science. It is also embedded in the current NGSS (NRC; 2013) When students work collaboratively and pose each other questions, then evaluate each other's answers, students act like scientists. That is how scientists communicate together in the real world. Numerous researchers argued that asking questions is a big component of critical thinking and problem solving. Dorri and Herscovitz (1999) study done with the 10th graders in the environmental science class required students to pose questions while practicing several educational tasks, such as interpreting and analyzing graphs, reading scientific articles, making posters based on their research findings. The post-test results of this study showed a significant increase in both the number of questions asked and their quality/complexity. Because of the positive outcome of this study, Dorri and Herscovitz recommended implementing question generating tasks as an alternative students' evaluation/assessment method.

The study by Chin & Osborne (2010) found a similar result: questioning serves a key component in science education. Their study's QA model (Questioning-Argumentation) revealed that providing students with opportunities to generate their own questions can elicit challenges for students. Posing questions to the self and other group members can inseminate cognitive conflict which may help students in engaging in argumentation by providing a strong evidence, argument and counterargument. It may also help students in uncovering the connections among the data, evidence and theory, thus fulfilling one of the aspects of nature of science.

For the above-mentioned reasons, this current study was focused on the questioning patterns that occurred in the course of group discussions in socioeconomically diverse high schools.

Literature Review

What is considered good questioning? Is it a skill that students can learn? If students ask higher-level questions, does it mean they also think critically? Is there a correlation between good thinkers and good questioners (King, 1995)? Can teachers teach their students to develop, pose and answer higher-level, critical thinking questions? Can teacher intervention eventually lead to the situation when students formulate good questions autonomously? These are some key questions that the researchers, who study high-level questioning in student discourse during group discussions, want to answer.

<u>Teaching Strategies</u>

When students were asked to formulate questions, they generally came up with low-level, factual questions (Dillon, 1988; Flammer, 1981). For that reason, it is very important to develop high-level questioning strategies that can be taught to students so they can start using thought-provoking, high-level questions during their discourse. The research shows that students develop deeper understanding, better thinking and learning, when they use or are exposed to higher level thinking questions (Almeida, 2012; Coutinho & Almeida, 2013; Graesser & Olde, 2003; Kuhn, 2009, Wolfe & Alexander, 2008). These types of questions help students analyze, synthesize, and evaluate, while they are engaged in problem solving activities. Indeed, students will take a pragmatic approach toward their problem solving tasks if they formulate higher order thinking questions prior to tackling the given task. Likewise, students gain deep knowledge when they are exposed to open ended questions that may have more than one possible answer, or have no right/wrong answers. Quite the opposite, low level questions require knowledge, memorization, have right/wrong, already known answers, elicit little or low level learning.

Wolfe and Alexander (2008) argued that challenging students to engage in argumentation would increase students' critical thinking and reasoning by empowering students to ask questions and reflect critically on their newly gained knowledge. Still, the classroom observations showed that most questioning patterns used in the student discourse were comprised of questions and answers requiring recollection/restatement of known facts. The findings of Wolfe and Alexander were consistent with the results of the comparative analyses conducted in five countries: England, Russia, India, France and United States (Alexander, 2001). In addition, various studies have consistently showed that most classrooms were dominated by the teacher talk, where only a few students asked questions (Almeida, 2012; Almeida and Neri de Souza, 2010). Moreover, only a small percentage of students are able to generate higher order thinking questions whereas the most questions formulated by students are low level questions which leads to lower achievement.

What changes in questioning can lead to better educational outcomes? Wolfe (2006) suggested that teachers should challenge students' thinking by asking authentic questions and providing opportunities to students to ask questions as well. Also, fostering student questioning would help teachers to concentrate on constructivist pedagogy by moving from the teacher-centered teaching to the student-centered teaching and learning (Almeida, 2012). To make this transition successful, students may need an explicit and detailed instruction for question generation: effective questioning techniques will require a proper training of questioning skills (Graesser & Olde, 2003). For example, a qualitative study with the 9th graders in the science class conducted by Coutinho and Almeida (2014) revealed that the use of various question-promoting strategies caused a decrease in the number of closed questions whereas the number of open questions increased. Personality and cognitive ability tests conducted by Graesser and Olde

(2003) revealed that although good comprehenders asked fewer questions, they have asked high quality good questions. Also, while testing their predictions of a cognitive model of question asking, these researchers realized that students ask better questions when they are faced with ill-structured and anomalous conditions, which they have called a "cognitive disequilibrium." As they indicated in their paper (Graesser & Olde, 2003, p.524): *"Questions are asked when individuals are confronted with obstacles to goals, anomalous events, contradictions, discrepancies, salient contrasts, obvious gaps in knowledge, expectation violations and decisions that require discriminate among equally attractive alternatives. The answers to such questions are expected to restore equilibrium and homeostasis."*

King's (1995) model, of inquiry has demonstrated that providing students with thought-provoking question stems can induce critical thinking processes in them. In her study, students were asked to generate questions to which they did not already know the answers. The result of the study showed that when the students are presented with the exemplar question stems and are guided by the teacher, students can not only learn good questioning techniques, but also do it speedily.

Various studies conducted in classrooms show that teachers use "closed" questions whose answers are already known most of the time, in other words questions that have right/wrong answers (Dillon, 1988; Rojas-Drummond, 2003). This type of discourse is not very productive because it does not provide students with opportunities to elaborate and come up with long explanations. In contrast, when the teacher is posing higher-level questions, s/he may also model a useful questioning technique that students can assimilate and use in their student-led group discussions (Chin, 2007). For example, debating activities in the classroom could provide teachers with excellent opportunities to expose their students to the questions and topics that are controversial and do not have a “right” answer to them (Bull, 2007 & Lilly, 2012).

Several educational researchers have critiqued the IRE (Initiation, Response and Evaluation) questioning model and have revealed its prevalence in various classrooms regardless of the subject and grade level (Vaish, 2008). Lee (2007) did not look at the limitations of the IRE model but rather focused on the model’s usefulness for understanding classroom interaction. Lee’s fine grained analysis were conveyed toward the third turn position in teacher talk which provided the teacher with the opportunities to correct students’ misconceptions and errors, helped students to reconstruct questions and teachers to evaluate students’ response. Moreover, he recognized that the third turn, the evaluation/feedback part, may provide educators with analytical possibilities for understanding students’ identities, also their knowledge and skills.

Teacher talk should be corrective and nuanced so it does not overwhelm student to student interactions. Indeed, as Burns & Myhill (2004) found, “The more questions teachers ask, the fewer children say.” Even though it is generally beneficial to have less teacher talk and more student to student interactions in the classrooms, teacher talk plays an important role in helping students learn. For example, the research conducted by Gillies (2004) indicated that when teachers were trained to use specific communication skills, they were able to engage in more mediated-learning interactions, asked more questions and had fewer discipline problems in contrast to their peer teachers who did not get the training. Moreover, these teachers’ behavior served as great models for their students who in their turn provided detailed explanations and asked more questions. This study’s finding about the benefits of teachers asking many questions (due to their special training) seems to contradict Burns & Myhill (2004, p. 47) research.

Additional research is needed in variety of subject areas in order to determine if there is any negative correlation between the excessive teacher questioning and student learning.

Collaborative Learning

Some researchers use cooperative and collaborative learning terms interchangeably. Smith et al. (2005) highlighted that both pedagogies influence peer interaction. However, they draw clear distinction between them by stating that "cooperative learning requires carefully structured individual accountability, while collaborative does not" (p.2).

If learners are exposed to the student dominated discourse and are trained to ask higher level thinking questions, then students may pose questions to each other and answer these questions, supporting their points of view by providing strong evidence. By placing students in small cooperative groups, teachers can teach special techniques that can not only help students to formulate their own questions, but probably provide every student in a group with a chance to participate and express his/her own voice.

Student interactions that promote better outcomes in collaborative settings were carefully examined. It was established that elaborated discussions lead to better learning outcomes. Asking questions during group collaboration was positively related to achievement provided it led to receiving explanation instead of just receiving the fight answer (Webb, 1982). In fact, receiving explanation and, subsequently, carrying out constructive activity was found to be significantly beneficial than just receiving the right answer. On the other hand, not receiving help after making errors and asking questions could negatively impact student achievement.

The research conducted by Mercer et al. (2004) found a correlation between improved reasoning and language skills which led to 'higher level of attainment in their study of science' (p.373). In addition, they acknowledged the fact that language skills can be taught and learned.

In their qualitative and quantitative study with elementary school children, Mercer & Wegerif (1999) found that students, who are explicitly taught the language for reasoning while carrying out collaborative activities, were better in problem solving than the students who were not exposed to the “ground rules.” Providing students with the “ground rules” opens up several avenues for students in addition to increasing their collaborative reasoning. For example, classroom teachers and researchers indicate that those “ground rules” create an intellectual environment, make the class atmosphere more receptive, and allow students to encourage each other. Moreover, these “ground rules” create a neutralizing environment where confident students have an opportunity for being open to varied and diverse views, whereas the quieter students feel the freedom of contributing to the group, by acknowledging that their opinions are appreciated and are taken under consideration (Mercer, 2004). Mercer’s study used the TRAC (Talk, Reasoning and Computers) project which was mostly made up of collaborative activities. The Raven Progressive Matrices test scores, measuring the effects of the project on students’ reasoning ability, were analyzed before and after the introduction of the program. The study found a significant difference between the pre-test and post-test scores. Mercer and Wegerif (1999) described the exploratory talk in the following way: “Exploratory talk is that in which partners engage critically but constructively with each other’s ideas. Statements and suggestions are sought and offered for joint consideration. In exploratory talk, knowledge is made publicly accountable and reasoning is visible in the talk” (p. 97). If students are trained in posing and answering higher-level questions, then they can also be easily engaged in exploratory talk.

King’s (1991) study with elementary school students showed that students in groups with guided questioning outperformed students in unguided (this group was told to ask and answer questions) and in control (this one received no instructions about the questioning) groups.

According to this study, the usage of strategic questioning increases students' problem-solving skills by teaching them how to ask for and provide elaborated explanations during the problem-solving process. This improvement of problem-solving skills leads to better student learning. Whenever students are exposed to guided questioning techniques and they consciously use them in their peer or group discourse, the discussions become more interesting and productive because those high-level questions spawn intricate, thoughtful responses and explanations. King's (1990, 1991) findings align perfectly with those of Webb (1989) well known research on interactions in groups that demonstrated that the students who give explanations to others in the group learn the most. Deering and Meloth (1993) examined Webb's (1989) study on group interaction and learning, and found out that those students who provide high-level elaborations learn significantly more than their help recipient peers. Without teacher guidance, the collaborative learning occurring in "natural" settings leads to the low frequency of high-level talk (Meloth & Deering, 1993). However, the research shows that students can increase the frequency of their high-level talk, for example, effective argumentative discussions, during their collaborative group activities.

A scenario when students increase the frequency of their high-level talk was evident in the study done by Anderson et al. (2001) with elementary school children. Anderson et al. (2001) concluded that the effective argumentative stratagems after being picked up by a child can be employed and spread by other children. They dubbed this phenomenon as the snowball hypothesis. These researchers speculate that students who employ argument stratagem do not undergo the process of mimicry and, therefore, should not be considered copycats. What is more, students utilizing this stratagem probably have a good understanding of it as a useful tool and know when and how to use it. Anderson et al. (2001) found two more interesting factors in their study. First of all, they observed that the snowball phenomenon worked best in student centered rather than teacher centered discussions. Second, they noticed that after gaining and understanding the stratagem of argumentation, students may use it again and again. Anderson et al. (2001) study's results support King's (1991) findings where she found that the guided questioners were able to transfer their acquired skills about the strategic questioning to the novel problem. She also noticed that students demonstrated transfer while internalizing their new acquired questioning strategies from dyadic to individual context. Similar research results were obtained by Mercer et al. (2004) when the impact of intervention was checked after one year. The evaluation of its long term effects showed that students who received the intervention were still able to recall the ground rules and use them in their problem-solving activities. In contrast to above-mentioned studies, the research conducted by Gillies and Khan (2008) found opposite results. Their research indicated that there was no evidence of transferring oral discourse skills learned in RP-S (reasoning and problem solving) activity to the written task. Students need some time, repetitive instructions in order to process their newly acquired techniques, such as being able to provide meaningful justifications, elaborations and reasoning to the novel phenomenon.

Collaborative reasoning (CR) is an instructional approach that uses dialogical inquiry for small group discussions (Waggoner et al., 1995). When students are engaged in collaborative reasoning, they learn in better ways since they think collectively in contrast to thinking individually. The proponents of collaborative reasoning (CR) believe that effective dialog discussions help participants to develop better individual argumentation skills because they provide a developmental environment where students can experiment with a range of argumentation elements like reason, ground, warrant, and rebuttal. However, students should be explicitly taught special techniques that would help them to engage in argumentation whereas teachers should facilitate and scaffold small group discussions (Gillies & Khan, 2008). Accordingly, CR emphasizes the role of a dialog for teaching students how to think. Reznitskaya at el. (2009) reviewed numerous CR studies that were focused on (1) discourse patterns during CR discussions; (2) post-participation individual student outcomes; (3) the relationships between the discussions' quality and students' consequent performance. These studies clearly showed that the engagement in a collaborative reasoning dialogs helped students in developing and enhancing their argument schemas.

In Lilly's (2012) study with college students taking an Environmental Science course, students were given one week for their debate preparation and were also told not to focus on winning or losing situations but rather were instructed to collaboratively work on their dispute's rationalization. When students' debate positions were evaluated before and after debate, it turned out that an assigned debate position influenced student's opinion toward that position. Construction of strong argument mostly occurs when students are engaged in open-ended, real-world problems that have no right or wrong answers. This study raises a question: do students make better reasoning during the debate when they are assigned to a particular position or when they are given opportunities to choose a position for themselves? Depending on the answer, the teachers may need to plan the classroom debate accordingly in order to avoid any kind of bias, which may be the result of assigned debate positions.

Teachers play a major role in student learning in collaborative groups (Webb, 2009). They can employ various strategies for enhancing task performance and student achievement. For example, teachers may train their students in high-level discourse by providing explanation prompts. These prompts may include a variety of questioning methods such as metacognitive, strategic, comprehension and connection questions. When students are engaged in higher level cognitive tasks or in complex tasks like solving ill-structured problems, they often become aware of their own thinking (King, 2003). Additionally, while employing Guided Reciprocal Peer Questioning, students are encouraged to ask metacognitive questions which help students monitor and reflect upon their own thinking, problem solving and decision-making processes. Likewise, this approach helps students to clarify and correct their peers and their own misconceptions, fix any occurring errors and check their understanding. In reciprocal questioning, students are trained in such a way that peers exchange high-level thinking questions. If learners are engaged in a student-centered discussion, it does not mean that the teacher plays an observer's role. Students need guidance for questioning strategies, which will help them to become effective problem solvers. As King (1991) states, students may not be able to solve problems effectively if they are not explicitly trained to ask strategic questions. In other words, students need trainers or facilitators. Students are also required to monitor each other's thinking. Reciprocal questioning or guided cooperative questioning developed by King and Rosenshine (1993) was developed to engage students in an elaborative questioning paradigm that leads to knowledge construction. In reciprocal questioning, students are encouraged to ask each other high-level questions about the topic. It is believed that this type of questioning can help students monitor their own and each other's comprehension of the material. In addition, high-level questioning encourages students to explain and elucidate their thinking. Teachers' appropriate contribution to the collaborative groups may lead to productive outcomes by generating high quality student discourse (Meloth & Deering, 1993). Certain characteristics of instruction can promote high-level discourse. For example, teachers may model their own thinking and demonstrate strategies such as clarification, inference, question generation and summarization. Eventually, they can encourage the students to elaborate, justify, and explain their claims in order to support their conclusions. Teachers also can help students to make connections between the process (communication) and product (what was learned). Teachers, by employing certain guided questioning techniques or models such as King's (1995) model of inquiry, may promote their students' critical thinking. The reinforcement of these strategies can help students develop a habit of inquiry. The development of this habit can be simulated by posing questions modeled after certain questioning stems. For example, asking questions such as Why do you think so? Or What makes you think in that way? This questioning technique may be applied to subject areas and contents other than science.

Various research findings (King, 1991; Webb, 1982; Webb, 2009) show that teacher guidance including modeling and scaffolding was necessary for the productive cooperative group interaction. Furthermore, evidence existed that students had rare opportunities for learning specific strategies in order to communicate effectively in their cooperative groups (as cited in Mercer, 1995). Some studies revealed that teachers very often encouraged students to talk and make decisions or reminded them to discuss the proposed topic in the group without guiding/teaching them how specifically to use language. The teacher guidance is necessary in every classroom, may be even more in science classrooms. Not offering guidance in science classrooms may lead to an ineffective learning in cooperative groups. Indeed, while conducting scientific investigations in science classrooms, students must describe their observations, ask questions, gather information, formulate and revise hypothesis, make inferences, analyze their collected data, and come up with conclusions and claims that need to be supported by the valid evidence. Those are not trivial, routine activities. In order to perform them effectively, some level of guidance is essential.

Teachers should make sure their students have a clear understanding of the cooperative learning norms. For example, students should know that sitting at the same table and having one student accomplish the task while the rest of the group members just add their names to the assignment does not mean that they work cooperatively. Cooperative learning is not merely sitting next to each other. It is about tackling, discussing and solving the proposed task together as a group. Because cooperative learning encourages students to learn more and promotes higher achievement in contrast to individual learning, it makes sense for teachers to let their students know about the correct structure and positive outcomes of cooperative learning (Smith et al., 2005).

Tracking, socioeconomic status and urban education

The results of the study conducted by Radenbush et al. (1993) showed that there was not enough focus on high level critical activities in low-track math and science classes. Other researchers obtained similar results (Torff, 2006; Zohar & Dori, 2003; Zohar & Vaaknin, 2001). They found out that teachers differentiated their instructions according to their beliefs that higher order thinking was appropriate only for high-achievers. As a result, low-achieving students were continually exposed to lower order instruction which led to a widening gap between low- and high-achieving students. The study that was done with Israeli teachers showed that 45% of teachers believed that higher order thinking activities were not appropriate for low achieving students. In order to validate that students in all academic levels should be a target of teaching higher order level thinking skills, a group of researchers (Zohar & Dori, 2003) designed an experiment to teach higher order thinking skills in science classrooms. According to their research results, “The compelling empirical evidence shows that low-achieving students and higher order thinking are not mutually exclusive” (p. 177). Therefore, this study showed that low achieving students can benefit when exposed to activities that require higher order thinking skills.

Anyon suggested that student work in working-class classrooms is very different from student work in middle-class or affluent classrooms (Anyon, 1980). In working-class schools science education tends to be simplistic and mechanical. Quite often teachers retell students the same material that the textbook says. Students spend significant time just copying the teacher's sentences from the board. The experiments are scarce and lack analytical examination. The study also indicated the shortage of good explanations and the prevalence of primitive discourse in these classrooms. Rubin's study also showed the insufficiencies of discourse and interactions in poor, urban schools (Rubin, 2007). According to this study, these deficiencies created a learning environment where only few students can succeed. Most of the students were destined to fail in this environment. Therefore, it is necessary to switch to discourses and interactions that can promote competence rather than incompetence. Regrettably, despite strong indications that student discourse and interactions in urban or socioeconomically diverse schools are woefully inadequate, there has not been sufficient research done examining and analyzing the quality of questioning during student discourse in urban/ socioeconomically diverse high school classrooms.

Method

This research study provides a better understanding of discourse patterns during collaborative group discussions involving high school students from an East Coast socioeconomically diverse school district. Specifically, the study focused on the following research areas: a) the types of discourse used during collaborative group discussions in a socioeconomically diverse high school, b) students' use of high-level questioning during collaborative group discussions. This research piloted a new approach in teaching students how to ask and answer higher order thinking questions which in turn should improve students' critical thinking skills.

Although the proposed strategies and models in this article can be used in any subject area and grade level, this particular study focused on high school science. The Project 2061 defines and emphasizes the importance of increasing scientific literacy (AAAS, 1993). Just having scientific knowledge is not enough; we want our students to be fluent in scientific talk, such as in scientific argumentation and scientific explanation, where posing and answering thought provoking questions might be a key avenue for successful science learning. Lemke (1990) highlighted the idea that science education should provide students with opportunities to become "fluent speakers of science" (as cited in Mercer et al, 2004). In the same spirit, Zint & Peyton (2001) suggested incorporating 10 risk education goals into students' learning in order to prepare them as future decision makers about health and environmental risks. These goals aimed at improving students' evaluating skills in regard to differing perceptions of risks, the benefits and limitations of the scientific approaches used to estimate the type and size of the risk, and the effect of personal biases on their and others judgment about the size of the risk. In order to achieve these goals, students needed to engage in the high cognitive tasks requiring deep understanding of the content. Earlier, an environmental educator Riechard (1985) has stated that people, who are literate in environmental risk education, have great inquiry skills and are critical thinkers and questioners; they are people who excel in analyzing the best information available in order to arrive to sound solutions.

Setting and participants

The school is located in a city in Northeastern New Jersey. According to 2010 census data, in this borough about 55.01% are White, 18.85 % are Black, 0.29% are Native Americans, 5.81% are Asian and 0.05% are Pacific Islander. Hispanic or Latino of any race was 44.21%. In the district about 50-60% of students are qualified for free/ reduced lunch. The student demographics are approximately 50% Hispanic, 20% Black, 20% White and 10% other.

Participants of the study were high school freshman students (N=14) enrolled in Mrs. Patty's Environmental Science course in Anderson High School. The research took four consecutive days. For the experimental study purposes the experimental groups were placed in different classroom, while their classmates were in their usual environmental science classrooms with Ms. Patty. Only students who had signed parental consent forms have participated in the study.

Data sources

Data of this study came from the audio and video recordings, classroom observations, field notes, and student artifacts. The audio and video recordings were transcribed and analyzed by the software Dedoose to get more accurate mixed data analysis. Additionally, both student artifacts and researcher's observations and field notes were used to clarify and resolve any inconsistencies, gaps or ambiguities in transcriptions caused by suboptimal recording quality. The topic used during this research was the green energy sources. Although four groups were participating in the pilot study and each group was discussing a one kind of renewable energy source, only one group, the Biomass group was chosen by the researcher for data analysis.

Research design

The study was about observing students' discussion patterns, teaching them how to construct high order thinking questions and observing/analyzing student generated questions in the context of renewable energy sources. The chosen topic was suitable for a study for a variety of reasons. First of all, it is a popular topic nowadays for our society and there are various differing clean energy ideas and suggestions about carbon free energy sources. Second, the broad topic of Renewable Energy Sources provided the researcher with the opportunities to divide the main topic into the subtopics, where each group would focus on one type of sustainable energy resources. Last but not least, since Ms. Patty had not covered the Renewable Energy Source chapter before this research's start, the students did not have to repeat it and fall behind on other topics because of this study.

The objectives of Day 1 can be divided into three parts: a) researcher introducing herself and presenting the goals of the study, b) checking students' prior knowledge and short lecture about the renewable vs. nonrenewable energy sources and c) small group discussion about the advantages of renewable energy source.

Because of scheduling conflicts and difficulties with availability of free classrooms, the researcher had the entire class (including non-participant students) in the same science room. However, recording devices were directed only towards the participants with signed consent forms approved by the IRB and data was collected only from those students. Study participants from both control and experimental groups participated in Day 1 study. These students were broken into four collaborative groups: two groups were seated in the front of the classroom whereas the other two were in the back of the classroom. Both front groups had three students each whereas the back groups had four students per group.

The researcher's introduction of herself and presentation of the goals of the study was followed by checking students' prior knowledge and a short lecture about the nonrenewable energy sources (fossil fuels and nuclear energy). Since students were previously taught nonrenewable energy sources, they already had background knowledge about it. Researcher's lecture gradually shifted toward the nonrenewable energy sources, which was the main topic for study. She talked briefly about each of the renewable energy sources yet being careful for not providing too much information.

According to the designed research protocol, each group was expected to work on one kind of renewable energy source. Four renewable energy sources were arbitrarily assigned to each collaborative group. The researcher had the names of the renewable energy sources written on index cards and randomly placed the index cards on the desks. Although each group's topic was assigned by the researcher, the group facilitators were chosen by their teacher, Mrs. Patty, since she was the one who was familiar with her students' academic levels and their study skills. The facilitators were chosen based on distinguished note taking and leadership skills. Every facilitator was given a handout, where they were asked to jot down their group members' discussions. The handout had three columns: initials, short description and details (See Appendix A for a sample handout).

In order to optimize student motivation and facilitate discussion, every group member including the facilitator in each group received a handout called "Renewable Energy: Panacea or Pipe Dream?" The front of the handout had information about the goal of the discussion. For example, there was mentioned that the goal of the discussion was to develop a compelling justification for the increase of the production and use of renewable energy. The handout also included recommendations for their discussion. For example, the students were asked to develop alternative viewpoints on the subject such as letting the market forces and/or technology decide renewable energy's future instead of taking an activist position. Furthermore, students were given written directions about utilizing any fact or argument that they have obtained from their previous lessons and other sources like magazines, Internet or TV. The back of the handout had a list of some suggested discussion items. Students have advised to read them and use as guidance. The suggested items were divided into three main topics: a) the need of renewable energy, b) renewable energy in developed and developing worlds and c) energy and politics. Each topic in its turn was divided into subtopics. This table summarizes the information provided on the back of the handout:

The need of renewable energy	**Renewable energy in developed and developing worlds**	**Energy and politics**
Environmental reasons	More affordable in developed than in poor countries	Politics of renewable energy in United States
Economic reasons	Environmental pollution in developing worlds	Fossil fuels and geopolitical considerations
National security reasons	The need of transition to renewable energy in developing world	Kyoto protocol and the future of climate treaty
Moral reasons	Developing and sharing green technologies	Carbon tax versus cap and trade
Green energy and jobs	Financial aspects of the move to renewable energies	
Green energy and innovation		

Students were asked to utilize their textbooks (Environmental Science by Karen Arms, published by Holt, Rinehart and Wilson, 2008) for group discussion. Some suggested items in the handout were not addressed in the textbook. Students were expected to use their prior knowledge they have gained while watching TV, reading a newspaper or magazine article or reading pertinent information in Internet. All the above mentioned was also written in the provided handout.

The objectives of Day 2 were to introduce students to high order thinking questioning techniques and help them to recognize and evaluate the differences between low and high level questioning. In addition, students were asked to practice making high level thinking questions in the context of renewable energy sources by using question stems that were adapted from Alison King (See Appendix A for the sample). For that purpose the researcher met only with the experimental group. These students (N=8) were randomly chosen by Mrs. Patty. They went to their regular classes, got marked "present" for their attendance, and then came to the classroom where the experimental instruction took place.

At the beginning of the lesson the researcher posed the following questions: "What is considered good questioning?", "Do you think there is a correlation between good questioning and good answering? Justify your answer.", "Can you come up with low level (bad) questions?", "Can you come up with high level (good) questions?"

After getting some responses from the students, the researcher explained that according to much research, high level thinking questioning promotes critical thinking skills, develops deeper understanding, better thinking and learning. She also highlighted that, according to the research based evidence, low level questioning relies on prior knowledge, memorization, and right/wrong answers. This type of questioning limits interpretation, depends on already known answers and, eventually, promotes low level learning. After the short introduction of questioning techniques, the researcher posed several questions and had students to analyze the types of questions and answer them as well. The posed questions were progressing from the most simple (low level) to complex and difficult (high level) questioning. For example, the simplest question which checked students' knowledge was "How many renewable energy sources are there?" Here are some examples of posed high level thinking questions: a) What are some problems associated with using hydroelectric energy? (Analysis) b) How could you design a house which would mostly rely on renewable energy sources? (Synthesis) c) Can you develop a proposal to the mayor of your town in which you would suggest the immediate action of using renewable energy sources? (Synthesis) d) What evidence would you use to show the possibility of transferring wind energy from rural to urban areas? (Evaluation)

The main idea of this activity was to have students realize the differences between low level and high level thinking questions and the kind of explanations that followed from those questions. After a short lecture, each student was given a question starter adapted by Alison King and was asked to generate questions on the topic of renewable energy sources by utilizing the provided question starters. Students were asked to work in groups in order to formulate and answer their own questions.

The objective of Day 3 was to have students work in collaborative groups and make high level thinking questions, by utilizing the question starters (Day 2's handout) and the suggested items' list (Day1's handout). Only the experimental group participated in Day 3 study. The experimental group participants (N=8) were divided into two groups: four students in each group. Like in Day 2, there were no facilitators assigned in Day 3. Moreover, the researcher announced that each group member was expected to contribute to the group work because the previous day's study showed that most of the groups were dominated by one student. In addition to the handouts that were used in Day 1 and Day2, every student received the third handout called "Statement/ Opinion Day3" (See Appendix A for the Statement/ Opinion Day 3 handout). The students were engaged in a whole class discussion of sample questions which were high level thinking questions based on renewable energy sources. The purpose of this procedure was to show students how the construction of the high level questioning leads to a productive explanation. The students were encouraged to re-read the handout about the good questioning and answering, which was meant to serve as a model for their Day 3 activity.

The objective of Day 4 was to discuss the disadvantages of using renewable energy sources and, like in Day 1, both control and experimental groups were present in the study. For Day 4, all students got suggested items' list, similar to Day 1. The difference was that students were asked to focus on disadvantages rather than on advantages of renewable energy sources (Check Appendix A for a sample handout). Every group had a facilitator, just like in Day 1, and there were no question starters provided to any group.

Data analysis

Critical thinking has ancient roots that date back to the Hellenistic era. There is historical evidence based on Aristotle's and Plato's manuscripts that Socrates (470-399 B.C.) challenged his students with good questioning which promoted critical thinking. Considered one of the founders of Western thinking, Socrates was believed to make his students evaluate their beliefs and to encourage his students to formulate their own hypothesis. In one of Plato's manuscripts, there is a segment about Socrates teaching complex geographical principles to a slave boy. After the boy learned about this complex concepts, Socrates gave credit not to his direct teaching but rather to asking the right questions (Tweed & Lehman, 2002). Socrates' probing questioning techniques started to get widespread, especially in educational institutions. Various educational researchers have acknowledged the importance of questioning strategy in education. A classical research study revealed that teachers spent 80% of the school day on asking questions, and they asked about 300-400 questions per day (Leven & Long, 1981). Numerous research studies stated that most of the questions asked in the classrooms did not have high quality (Graesser & Person, 1994, Seymour & Osana, 2003, Walsh & Stattes, 2005) unless teachers were trained in effective questioning such as inquiry-based teacher questioning (Oliveira, 2010).

The research interest of this pilot study was not about teachers' but rather students' questioning and discussion techniques. Particularly, the focus was on higher cognitive level discourse, which would help students to construct their own knowledge/information and solve problems that are related to the real world. The Nobel laureate in physics Isidor Rabi contributed his great questioning skills to his mom, who asked him everyday about the good questions that Isidor asked at school (King, 1995).

Since the teacher is the primary questioner in the classroom, it was interesting to observe students playing an active role in the classroom, asking questions to their peers rather than being questioned by their teacher. Research also showed that students did not ask questions spontaneously, however with their teacher's help and guidance students can generate meaningful questions (Chin & Osborne, 2008). Moreover, when teachers stimulate their students to generate higher level thinking questions, it could help students monitoring their own thinking and expressing their voice. Teachers can create such an environment where students' generated questions may spawn another set of questions. Critical thinking will be initiated when instead of asking questions that have dead-end answers, questions leading to another set of questions are practiced among the students (Toledo, 2006). The study done with the MBA students taking an online course revealed that more controversial point of views supported students' critical thinking (Jeong, 2003). Interestingly, their sequential analysis which studied student interaction in the online discussion threads aligned well with this pilot study. Although the current study was conducted with much younger students, there were several fragments observed when more contradicting ideas lead to more discussion, where students were thinking critically while supporting their argument.

Walsh and Stattes (2005) found that teachers' questioning quality has not been changed in the past 100 years. It therefore becomes evident that there was more focus on the quantity, rather than on the quality of the questions. Isn't it better to ask fewer questions but questions that have high quality, questions that stimulate student thinking, and questions that promote deep learning vs. surface learning? Anyway, how is the quality of questions determined?

American educational psychologist Benjamin Bloom has made a significant contribution to this field with the formation of what became known as Blooms taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Bloom and his colleagues classified three different learning domains: cognitive, affective and psychomotor. Bloom's taxonomy of educational outcomes for knowledge-based goals has six different expertise levels. In this multitier framework, each tier expresses the measurable outcome of student learning where a learner can achieve that particular knowledge. Constructing questions based on Bloom's framework can be classified into two main categories: lower level and higher level questioning. Lower level thinking questions require knowledge, comprehension, and application whereas higher level thinking questions require analysis, synthesis and evaluation. Various primary, secondary and high educational establishments have incorporated Bloom's taxonomy in their instruction and assessment. Bloom's taxonomy was considered as a great model of learning objectives. It was around the mid-nineties, when Bloom's former graduate student, Lorin Anderson and his colleagues, decided to revise Bloom's taxonomy, in order to adjust new skills that 21st century students need to master. The new revised Bloom's taxonomy was not very different from the original model. There were two minor differences: 1) the nouns were replaced with verbs and 2) Synthesis, which was the second highest questioning level in Bloom's original cognitive domain, was renamed "creating" and was placed to the highest tier in Bloom's taxonomy. The "evaluation" category which was the highest rank in the old domain was replaced with the verb "evaluate" and was moved one tier down and was considered as a second highest level questioning in the new, revised model. The new updated domain consisted of the following thinking levels: remembering, understanding, applying, analyzing, evaluating and creating. The major difference between Bloom's original and the revised Bloom's taxonomy (RBT) is that the original taxonomy has single dimension whereas the revised taxonomy has dual dimensions: learning and cognition (Anderson & Krathwohl, 2001; Krathwohl, 2002). Furthermore, Mayer (2002) argues that the revised taxonomy's lower cognitive level is remembering, which requires a retention of knowledge whereas the rest of the tiers serve more complex function. The rest of the five cognitive processes, understanding, applying, analyzing evaluating and creating, can promote learners to use their new acquired knowledge in different domains or situations, which initiates the cognitive process for transfer. As Mayer (2002) has stated "retention focuses on the past; transfer emphasizes the future." (p. 226)

For question analysis and coding purposes "Questions to provoke critical thinking" table was used, which was created by the Harriet W. Sheridan Center for Teaching and Learning of Brown University. The Sheridan Center has used the thinking skills and example question stems based on Alison King's (1995) "Inquiry Minds Really want to Know: Using Questioning to Teach Critical Thinking." All questions from transcripts were identified and coded as procedural, clarifying, lower and higher level. Additionally, lower level questions were coded as Understanding or Remembering whereas higher level questions were categorized as Applying, Analyzing, Evaluating and Creating. It is worth to note that this kind of question categorization was slightly different from the Bloom's original taxonomy. In our analysis "applying" thinking skills was classified as a higher order thinking skill in contrast to Bloom's original taxonomy where it is considered as a lower level cognitive skills. Dedoose software was used for coding students' questions and analyzing the study's data.

Results

The group discussions were proceeding in an amicable and respectful environment. Students showed an open minded sociocognitive behavior. Repetitive observations of the Biomass group revealed absence of any emotional discomfort. Also, students mostly relied on their prior knowledge and short class discussions rather than on the information from their textbook. As revealed by the transcript (Day 3 - Fragment 3, Day 4 – Fragment 3), students had some obvious misconceptions. One area of misconception was the role and location of ozone layer. Another topic of difficulty was the connection between the national security and renewable energies. Even though these misconceptions prevented students from developing their topics in depth, they did not render the discussions useless for the purposes of this study: the use of questions to simulate a thought-provoking discourse was evident in those fragments.

There was a noticeable difference between observed questioning patterns pre-treatment (Day 1) and post-treatment (Day 4). First, Day 1's discussions were dominated by the facilitator with low participation by other students whereas during Day 4 almost all students were engaged and motivated. Even though it was apparent that the facilitator had excellent leadership skills and continued to be an energetic participant, other group members were actively engaged in the verbal discourse while carrying a high level talk. Second, the transcripts showed that during Day 1 almost all discussions followed the pattern in which the facilitator would engage other students one after another but there was almost no interaction between other students. To summarize, the discussions pre-treatment mostly followed this pattern: F (facilitator) – S1 (student 1), F-S2, F-S1, F-S3, etc. With more engagement and participation, the discourse switched to more interesting patterns like F – S1 – S2 – S1, F – S3 –S1, etc. Third, dynamics of group discourse during Day 4 showed productive patterns of questioning involving making claims, counter-arguments and using rebuttals. This in turn promoted students' critical thinking. Furthermore, there were several fragments observed when group members posed explanatory questions to each other in order to explore the group members' initial superficial response. These kind of questioning techniques have encouraged students to be engaged in discussion which lead to more productive student talk (Day 4-Fragment 1).

It appears that after teaching practices promoting higher level thinking questioning were applied during days 2 and 3 practices, there was a positive transformation in the Biomass group. It was also evident from the repeated observations and transcripts of recordings that the Biomass group was working more collaboratively and cooperatively in Day 4, compared with prior days.

Interestingly, this transformation happened gradually as the study progressed. In Day 3 students were able to self-organize by assigning a leader and dividing the job among the group members (Day 3 – Fragment 1). Day 3 seemed to be pivotal in making discussions more interactive and engaging. All students except one were actively engaged and were generating ideas and questions as revealed by these discussion excerpts: Day 3 – Fragments 2 & 3. It is possible that this phenomenon was triggered by several factors: a) Using thought-provoking higher level questions helped to make the discussion more interesting and engaging, b) The students got used to collaborative learning and started to feel more comfortable around each other, c) The researcher's proposal that each group member needed to contribute to the group work may have positively influenced this, d) The group was better structured with each group member knowing the subtopic that they would use for generating questions. Another important factor was the effectiveness of questions stems in helping students generate higher-level thinking questions. Most questions generated with the help of the question starters were sense-making questions. The students had no problem in taking the question stems, making questions based on the assigned topic and creating sense-making questions. These questions, along with their provided explanations, are listed in Day 2 – Fragment 1.

What was the nature of questions raised during the discussions? The analysis of the groups' discourse revealed four types of questions being utilized by the group members (based on the Bloom's taxonomy). The questions were classified into the following categories: procedural, clarifying, lower and higher level. Lower and higher level questions in their turn were broken into subcategories. Lower level questioning was divided into 2 subcategories: remembering and understanding, whereas higher level questioning was broken into four subcategories: applying, analyzing, evaluating and creating. Interestingly, lots of questions were clarifying questions. This observation was true for both pre-treatment and post-treatment discussions. Probably, this result should not be surprising because the very nature of group discussions compels students to ask for clarifications. Procedural questions were few so they were ignored in this study.

The next category of questions of interest were lower and higher level questions. Higher level questions were predominantly evaluating questions. How often and under what conditions were higher level thinking questions utilized? There were total twenty lower and higher level questions recorded in Day 1: thirteen of them (65%) were higher level thinking questions (see Table 1). Out of seventy four questions recorded in Day 4, where forty of them were higher level thinking questions and seven questions were qualified as lower level thinking questions (see

Table 3). The group members' contribution to the group discussion revealed that 85% in contrast to 65% of questions raised in Biomass group were higher levels, while only 35% of questions were lower level questions. Although many questions were still raised by the facilitator, the rest of the group members contributed significantly more to their group activity in Day 4 than they did in Day 1 (see Tables 2 & 4).

How were higher level questions taken up by students' peers? It is obvious from the transcript that these questions spawned thoughtful responses and led to active discussion. Additionally, they triggered alternate ideas/suggestions by other participants. Here are some noticeable talk invitations and questioning techniques used by the students that made the discussion more constructive and interesting: a) posing an open ended question as invitation to group to a meaningful discussion (day 1, fragments 1&2), b) pressuring group members for more elaborative explanations (day 1, fragment 3), c) making predictions by posing a question (day 1, fragment 4), d) raising ethical, social and moral issues to compel students to come up with alternative ideas (day 1, fragment 5), e) engaging non-talkative students into discourse by bringing up pressing questions (day 4, fragment 1), f) forcing the student to elaborate by questioned the accuracy of his statement (day 4, fragment 2), g) making claims, rebuttals and counter-arguments to construct explanations and engage into thought-simulating discourse (day 4, fragment 3&4, h) generating explanations, including an evidence and reasoning, and scientific predictions (day 4, fragment 5). In addition, when higher level thinking questions were used, they usually led to better scientific explanation and more productive discussion. It allowed students to explore their topic in more depth. For example, Day 1 - Fragment 6 indicated how higher level thinking questioning promoted to better scientific explanation.

Summary

This study characterized the discourse patterns of socioeconomically diverse high school students in Environmental Science classroom. It also examined the frequency of usage of higher order thinking questions, their nature, situations where they are used and their impact on student learning. Numerous previous studies showed positive impact of higher order thinking questioning on problem solving tasks (King, 1991; King 1995; Zohar, Degani & Vaaknin, 2001). Many science education researchers stress the importance of the development of higher order cognitive skills where critical thinking and problem solving skills are intertwined with question asking and decision-making (Zoller & Pushkin, 2007). However, these studies were predominantly conducted on elementary and middle school students or with college students. In addition, there was not enough research done on discourse patterns in socioeconomically diverse high schools.

Some studies conducted on low achievers showed similar results in regard to the usage of high level critical thinking activities. Their findings demonstrated that low track students were not sufficiently exposed to higher cognitive level activities because of the beliefs of their teachers (Zohar & Vaaknin, 2000, Torff, 2006, Zohar & Dori, 2003). These studies highlighted the fact that low achiever students were not exposed to the instruction which required higher cognitive skills. Nevertheless, there is not enough empirical evidence about the usage of higher thinking questioning and activities in science settings in socioeconomically diverse or urban high schools. This study provided with useful data about the discourse patterns and questioning techniques in socioeconomically diverse high schools which, after proper analysis, may be helpful for honing science instruction in urban or socioeconomically diverse high schools.

It should be noted that this study had some limitations. For example, the Biomass group's composition was not the same throughout the study. Although the group members stayed the same during Days 2, 3 and 4, two students were not present in Day 1 study. Another limitation of this study was the homogeneity of groups caused by making the group based on students' preference. Would the discourse have a different pattern if the group was heterogeneous by student gender? Would Taishae participate more rather than stay silent most of the time in Day 2? Lastly, there was a problem with the time allocation.

Suggestions for future study include conducting a study with much larger sample, making heterogeneous groups and providing equal amount of time for the pre-test and post-test. The research questions are not recommended to be changed or revised. The answers of these questions would provide educational researchers with valuable insight regarding the discussion patterns and the usage of higher-level thinking questioning in collaborative groups in socioeconomically diverse high schools.

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APPENDIX A

Day 1

Handout #1 for group discussion

Discussion's topic

Renewable Energy: Panacea or Pipe Dream?

During this group activity you will discuss the benefits and feasibility of the usage of renewable energy (solar, wind, biofuel, geothermal, hydropower) instead of nonrenewable forms of energy (fossil, nuclear). Each group will be focused on a specific type of renewable energy (your group's facilitator will tell you which one). The goal of this group discussion is to develop a compelling justification for the increase of the production and use of renewable energy. You can also develop alternative viewpoints on this subject like not taking any activist position on renewable energy but letting instead market forces and/or technology to decide its future. When discussing this subject, you can use any fact and argument you have learned about these sources of energy during prior lessons. You can also use facts and arguments you have obtained from other sources like newspaper or magazine articles, Internet, TV, etc. The following list of discussion items will be beneficial during your discussion. Read it carefully before the discussion and use it as guidance.

Some suggested discussion items

1. The need of renewable energy
    a. Environmental reasons
    b. Economical reasons
    c. National security reasons
    d. Moral reasons
    e. Green energy and jobs
    f. Green energy and innovation
2. Renewable energy in developed and developing worlds
    a. More affordable in developed than in poor countries
    b. Environmental pollution in developing worlds
    c. The need of transition to renewable energy in developing world
    d. Developing and sharing green technologies
    e. Financial aspects of the move to renewable energies
3. Energy and politics
    a. Politics of renewable energy in the United States
    b. Fossil fuels and geopolitical considerations
    c. Kyoto protocol and the future of climate treaty
    d. Carbon tax versus cap and trade

Day 1

Handout #1 for group discussion "Renewable Energy: Panacea or Pipe Dream?"

Discussion's facilitator: ____________________________

The type of renewable energy for discussion: ____________________________

Group participants:

Participant (firstname lastname)	Initials

Discussion Notes:

Initials	Short Description	Details

Day 4

Handout #2 for group discussion

Discussion's topic

Renewable Energy: Costs or Disadvantages

During this group activity you will discuss the costs and disadvantages of the use of renewable energy. Each group will discuss one of the following types of renewable energy: solar, wind, biofuel, geothermal, hydropower. The group's facilitator will tell you which one before the discussion starts. During the course of this discussion you will need to come up with a list of convincing arguments against the production and use of renewable energy. When doing this, make sure you test your claims by comparing renewable and nonrenewable forms of energy (fossil, nuclear). For example, if you are going to argue that renewable energy will have a heavy cost on economy, make sure you compare it with costs of fossil fuels and nuclear energy. You should use facts and arguments you have learned during prior lessons. Additionally, you can use other sources of information: newspaper or magazine articles, Internet, TV, etc. The following list of discussion items can help you navigate throughout your discussion. Read it carefully <u>before</u> the discussion and use it as guidance.

Some suggested discussion items

1. Costs of renewable energy
    a. Impact on economy and jobs
    b. Environmental costs of renewable energy
    c. Ethanol production/subsidies and food prices
2. Renewable energy in developed world
    a. Pricier energy and needy families
    b. Carbon tax and its impact on economy
    c. Cap and trade – is this better than carbon tax?
3. Renewable energy and developing world
    a. The need of development and costs of renewable energy
    b. Who will finance the move to renewables?
    c. Poverty in developing world and renewable energy
    d. Fairness question – why should developing countries put breaks on their development than developed countries were polluting without any restrictions for hundreds of years?

APPENDIX B

Day1 - Fragment 1

(6) Maria: We just write down notes?
(7) Chelsea: I do, you have to discuss, so start discussing.

Day1 - Fragment 2

(9) Chelsea: So, what is your opinion on biomass guys?
(12) Chelsea: Ok…I would really like this debate going.

Although Chelsea has mentioned this phrase, the transcripts of the recording did not show any evidence of debate. However, by posing this open ended question, she was inviting her audience for a meaningful discussion.

Day1 - Fragment 3

(15) Maria: I believe that biomass fuel is one of the best renewable sources and has some downfalls in it.
(16) Chelsea: Like what?
(17) Maria: I am not sure, but I do believe.
(18) Chelsea: I actually agree with that statement, because renewable energy sources do have a downfall. So, Jeremiah, what do you think about it?
(19) Jeremiah: It does something to do with renewable and nonrenewable fields. Am I right?
(20) Chelsea: So, Maria, would you use biomass?
(21) Maria: I am gonna say no on that.
(22) Chelsea: Why not?
(23) Maria: Because, I just read in the book saying that cutting down trees is one of the weak sources of biomass that can cause the result of habitat loss, deforestation, and soil erosion...and it can cause harmful air pollution…

Lines 15 and 17 showed that Maria's explanation was based on her opinion and did not provide any evidence. Chelsea wanted to push Maria further and get more information from her (Line 16). Although Chelsea attempted to press her group members further for more elaborative explanations, however she shortly shifted her attention to Jeremiah with the same question (Line 18) and then to Maria regarding to a different question (Line 20). In Line 23, Maria cites a strong scientific evidence regarding supporting her claim (Line 21). Maria probably would not provide such a valid justification, if Chelsea did not push her further (Line 22).

Day1 - Fragment 4

(26) Chelsea: Maria, you were stating that you would not use it due to trees being cut down and you need wood and wood is a renewable resource. So, what if we planted as much as we cut down?
(27) Maria: Well, it could help, but it could take… Do you know how many years it takes for a tree to actually grow?
(28) Chelsea: Yeah, it takes a very long time.
(29) Maria: I do not think we have patience for that long.

Chelsea started her conversation in Line 26 by summarizing what Maria said before. Afterward, she made Maria to make predictions by posing a question (Line 26). However, Chelsea's question would have been more scientifically correct if Chelsea had said "planted more than we cut down" rather than "if we planted as much as we cut down."

Day1 - Fragment 5

(31) Chelsea: OK, but biomass (inaudible) produces gas, used for cooking and heating, so, what would you rather want: trees or living in the nice house?
(32) Jeremiah and Maria: laughter
(33) Chelsea: What would you rather prefer?
(34) Maria: I believe you should cut a certain amount of trees (inaudible…)
(35) Chelsea: I agree with you, that we should not distort the roots of trees; we should cut parts of it.
(36) Maria: At least, like trees, that already are dead, at least trees that look dead.
(37) Chelsea: So, we should cut partial parts of dead trees.

Chelsea posed this question to Maria and Jeremiah. Although this question did not require scientific thinking and explanation, it has raised ethical, social and moral issues. This question helped Jeremiah, Maria and Chelsea herself to come up with the idea of cutting dead parts instead of living parts of the trees for biomass use. Despite of the fact that the researcher had included 'Moral Reasons" subtopic in the suggested discussion items' outline, the students did not notice it, because they were not using the outline at all.

Day1 - Fragment 6

(54) Chelsea: Now, in the beginning that I had documented, you said that you will not use it, because it causes habitat loss, air pollution.
(55) Maria: All right.
(56) Chelsea: Why did you change your mind?
(57) Maria: Well, to be truly honest about this, there are other alternatives besides biomass. But overall, of course our benefits to like sun fuels also affects. But either way, I would just use it
(58) Chelsea: OK, so you would use it to your advantage. Well, it seems to do not care about the trees anymore.
The comment (Line 54) was directed to Maria. Chelsea's question on line 56 was a powerful question which made Maria think critically and make analysis about her own thinking. There is

evidence in the transcripts of the recording that Maria at the beginning of discussion had stated that she would not use biomass; she also brought up some evidence in order to support her claim. Shortly after the discussion turned into moral and ethical issues involving biomass, more specifically the usage of wood, Maria had changed her mind and then stated that she would use biomass. So, in this fragment Chelsea was trying to understand Maria's reasoning for changing her mind .Chelsea's question made Maria think analytical, who started to look at another way as a solution to a problem.

Day2 - Fragment 1

1. How are plant material and organic matter important for human health?
2. What do you think would happen to the environment if we cut down more trees?
    a. We would lose habitats and the ecosystem wouldn't be balanced.
3. What are the weaknesses of biomass fuel?
    a. It destroys habitats and requires tree cutting.
4. How could gasohol be used to decrease air pollution?
    a. It is healthier air than fossil fuels. It causes less air pollution.
5. Explain why biomass is necessary?
    a. It helps with cooking/ heating.
6. What is the difference between fossil fuels and gasohol?
    a. Fossil fuels pollute the air, but gasohol doesn't as much.
7. How are gasohol and fossil fuels similar?
8. How can biomass be used to damage the environment?
9. What does biomass mean?
10. Explain how biomass helps humans survive.
11. How does biomass relate to solar energy?
12. Give an example of how biomass is used.

Day2 – Fragment 2

(3) After the prolonged silence, Chelsea started: "*So, the first question could be like…hmm, so biomass is basically like plant material and organic matter, so…"*
(4) Barbara: *It could be like what is it?* (Barbara came up with low level question)
(5) Chelsea: (Chelsea did not comment to Barbara, but rather tried to come up with her own high level thinking question.) *Hmm, it could it be like…*
(6) Maria: *What page are we on?*
(7) Chelsea: *496, how, hmm, how are plant materials and manure important for human health? You see that? Also, while we are writing we have to answer it too.*
(8) Maria: *So, how plant materials…*
(9) Chelsea: *… and organic materials are important for human health?*
(10) Chelsea: *Then the second one… What do you think would happen to…? What do you think would happen to…?* (This response came after a considerable delay.)
(11) Barbara: *… energy sources?* (Barbara continued finishing up a question which Chelsea started to generate.)

(12) Maria: *… to an environment if we cut down more trees?* (Maria also tried to use the same question starter as Chelsea started to use, however she chose to come up with a different question.)
(13) Chelsea: *OK* (It seemed that Chelsea agreed with Maria's, not Barbara's question.)
(14) Chelsea: *And then for the third question we can say: What are the weaknesses of biomass fuel?*
(15) Maria: Umm (It seems that Maria easily agreed with Chelsea's question.)
(16) Barbara: *So, what are the weaknesses of biomasses?* (Barbara was just clarifying the question that Chelsea proposed, since she was jotting down the exact same question as the rest of the group members were writing.)
(17) Chelsea: *Biomass fuel* (Chelsea confirmed.)

This fragment demonstrates Chelsea's continued dominance during discussions in Day 2.

Day3 – Fragment 1

(1) Chelsea: *OK, who wants to be a leader?*
(2) Chelsea: *I guess I will be.*
(3) Taishae: *Yeah*
(4) Chelsea: *Oh, I guess I will be the leader. Hmm, so we are doing biomass, so, you did not get your textbook?*
(5) Taishae: *No*
(6) Chelsea: *Ms., can they go upstairs and get their books because we are going to divide the work?* (The researcher did not want student leave the classroom, so she suggested utilizing whatever materials they had)
(7) Chelsea: *Do you want to do environmental reasons?*
(8) Taishae: *I will*
(9) Chelsea: *Who wants to do economical reasons?*
(10) Barbara: *I'll do that.*
(11) Maria: *I want to do that, I am sorry*
(12) Taishae: Laughing…
(13) Chelsea: *And national security reasons... I will do that. I love the military and FBI*
(14) Chelsea: *Moral reasons, Taishae, you are doing this.*
(15) Taishae: Oh, what??
(16) Chelsea: *Green energy and jobs.*
(17) Taishae: *OK, I am doing that.*
(18) Chelsea: Barbara, you are doing that…
(19) Barbara: *I am doing nothing*
(20) Chelsea: *Yes, you are… You are doing…*
(21) Maria: *Economical…*
(22) Chelsea: *You are doing "Green energy and innovation." Maria that is what you are doing, OK?*
(23) Maria: *All right*

This short exchange showed how students in this group effectively divided the job among the group members. Not everything went smoothly though. It seemed that both Barbara and Maria *wanted to work on the "Economical Reasons" subtopic. Maria took over the subtopic that Barbara wanted to work on (Line 11) and Barbara was disappointed that she did not get her desired subtopic (Line 19). However, Chelsea quickly recognized this problem and was able to smoothly rearrange the subtopics (Line 22), and Maria acquiesced (Line 23).*

Day 3 - Fragment 2

(32) Maria: *What do you mean green energy and innovation?*
(33) Chelsea: *What?*
(34) Maria: *What does it mean? What does this topic mean?*
(35) Barbara: *The green jobs are jobs that are…* (inaudible)
(36) Maria: *But there is an innovation…*
(37) Chelsea: *Innovation, I am pretty sure is like …* (silence). *I do not know*
(38) Chelsea: *Do you guys know what innovation means?*
(39) Taishae: *Innovation? No, not sure.*

This discussion fragment shows that the entire group was engaged in dialogue. Maria felt comfortable asking her question about the innovation (Lines 32, 34 & 36). Although her group members were not able to assist her, they made an effort to help (Lines 33, 35, 37 & 38). It was also apparent from this dialogue that Chelsea was comfortable with her role. Even though she was not able to help her group and was asking the rest of the group members for suggestions, she was very open and honest about that (Line 38).

Day 3 - Fragment 3

(44) Chelsea: *So, national security*
(45) Taishae: *96*
(46) Chelsea: National *security is like a protection of United States. Biomass is like plant materials and stuff. But it's biomass fuel, so…*
(47) Taishae: *How is it harmful to people and whatever?*
(48) Chelsea: *The topic is "How is it harmful?" or how is it like?*
(49) Taishae: *I mean, if you are doing national security*
……
(56) Chelsea: *Biomass fuel is an energy source and national security is to have tanks, and all of the weapons.*
(57) Maria: *Wait, but would that effect the economy though?*
(58) Chelsea: *I do not think it would, because biomass fuel is actually… like causes less air pollution. That is the health side of it. But would it cost more to have it?*
(59) Taishae: *As an energy source?*
(60) Chelsea: *Yeah*
(61) Taishae: *I wonna think so. Yes, it would, 'cause…*
(62) Chelsea: *Like a fossil fuel (inaudible) as an energy source*
(63) Maria: *I think the energy source would possibly cost more that is what I wrote*
(64) Chelsea: *They do less harm*
(65) Maria: *It will do less harm but it will cost more*
(66) Taishae: *For environmental reasons, why biomass is a good source of energy or…*

(67) Maria: *Can we say how environmental reasons are good or how they are bad*
(68) Chelsea: Explain the benefits of having biomass fuel in the weaponadary world.
(69) Maria: *I have a trouble putting mine into a question.*

In this exchange Chelsea raised a question about the national security. All group members, except Barbara, were contributing to the discussion of this question. In contrast to Day 2, Taishae was actively participating by asking questions and suggesting ideas. However, his questions steered the group off the discussion topic: the national security. The question that he raised in Line 47 made Chelsea to clarify her questioning (Line 48). It is not clear why Taisahe brought up the "harmfulness" of national security. Their task was to focus on advantages, not disadvantages, of the renewable energy sources. It is evident from Line 56 that Chelsea understood what biomass was. However, she had no clear understanding about the connection between the national security and renewable energies. Maria brought up a good question (Line 57) that could have steered the discussion in the right direction. However, it did not catch the group's attention. This segment showed friendly peer interaction, active student participation (except Barbara), and a warm environment that allowed each student to make contribution. However, it did not turn out to be a productive discussion because students were not able to put separate pieces (biofuel and national security) together to form the big picture: the US oil dependency on Middle East and its impact on the national security.

Day 4 - Fragment 1

(98) Chelsea:*Barbara, what is your opinion of biomass and cost and disadvantages?*
(99) Barbara: *Can you repeat that again?*
(100) Chelsea: *Your opinion about cost and disadvantages of biomass. Would you use it?*
(101) Barbara: *No*
(102) Chelsea: *Why not?*
(103) Barbara: *Because it is too expensive.*
(104) Chelsea: *Too expensive?*
(105) Barbara: *Yeah*
(106) Chelsea: *I ask you: fossil fuels are cheaper but harmful to the air that we breathe. So, would you rather use a cheap stuff with bad quality or expensive things that could create a healthy environment?*
(107) Taishae: *But biomass is…*
(108) Chelsea: *Wait, wait, wait, this is hers…* (Referring to Barbara)
(109) Maria: *It is not your turn*
(110) Taishae: *Oh, my bad…*
(111) Barbara: (14) **S2:** *The cheaper there is, the worse there is…*
(112) Chelsea: *Fossil fuels are cheaper than fossil fuels, but are more harmful.*
(113) Taishae: *Aha*
(114) Chelsea: *Biomass is more expensive, but it creates healthier environment.*
(115) Barbara: *So, let's use a biomass, because it is healthy for the environment.*
(116) Taishae: *No, not really. Because if you are destroying the habitats and animals, causing the animals to go extinct, then you are messing up the food chain, then it will cause other problems…*
(117) Barbara: *Yeah, but wouldn't it be worse, if we use the other one?*

(118) Taishae: *Yeah, you are damaging the ozone layer and blah blah blah*
(119) Chelsea:*Look, you are using fossil fuels, and these fossil fuels are in our cars. You are polluting the air and every single day we breathe that air. If that is more… We are breathing in air. If you think about it, personally, if it came to me…*
(120) Taishae: *It is a loose-loose situation.*
(121) Cheslea: *Yeah, If it came to me and animals, and I am breathing like harmful air, I would honestly choose a biomass, even though…*
(122) Taishae: *Yeah, what's wrong?*
(123) Chelsea:*Yeah, either way, renewable or nonrenewable it harms the environment.*
(124) Taishae: *I do not know about solar energy though*

This fragment of conversation shows how certain talk moves and questioning skills posed by the facilitator (Chelsea)can engage non-talkative students into discourse. The transcripts of the recordings, the field notes and the researcher's observations showed that Barbara rarely participated in the group discussion. The group facilitator invited Barbara into the group discussion by asking Barbara share her opinion on a biomass, including its cost and disadvantages (Line 98). The facilitator also held Barbara accountable for her answers by bringing up pressing questions (Lines 102,104 & 106). This strategy did not discourage Barabara from participating; moreover, she seemed comfortable with answering those questions and expressing herself (Lines 101103, 105, 111, 115 & 117). Although some of her justifications were incomplete, the dialogue between Barbara and Chelsea made Barbara's thinking visible. Another interesting section of this fragment was Taishae's attempt of interjecting his thoughts into the conversation. Both the facilitator and Mariareminded Taishae that it was Barbara'ss turn (Lines 108 & 109) and Taishae respectfully acknowledged his "mistake" (Line 110). This example provides another evidence of a positive, friendly group environment where students were highly respectful toward each other.

Day 4 - Fragment 2

(162) Chelsea: *See with my argument is, that biomass does harm tress, does harm the animals, but so the fossil fuels. Fossil fuels harm humans more.*
(163) Taishae: *Not really, it does not harm humans.*
(164) Maria: *Yes, it does*
(165) Chelsea: *Fossil fuels don't hurt humans??*
(166) Taishae: *I said not that much, not in a major way, that human die right away.*
(167) Chelsea: *It will take years…We are breathing oxygen that has harmful chemicals in it*
(168) Taishae *But isn't it take long time to cut down a lot of trees But if you are using a biomass as a, as a …fuel, you need*
(169) Chelsea: *There are millions, billions of trees in the world*
(170) Taishae: *Yes, but if you are using biomass for energy source, you are going to need millions of millions of trees …*
(171) Chelsea: *So, do you think there is an alternative source instead of cutting down trees?*
(172) Taisshae: *I do not know. What else can you use?*
(173) Chelsea: *Exactly*
(174) Taishae: *What about the oxygen in the air? First of all, you still pollute an air.*

(175) Chelsea:*But with the fossil fuels is the same thing. Can you please define the fossil fuels and their impact on the environment?*
(176) Taishae: *I could do that but it is not gonna work that way.*
(177) Chelsea: *So, your argument is invalid.*
Laughing in the background

In this fragment the conversation was mostly between the facilitator and Taishae. The facilitator was the proponent of a biomass whereas Taishae was arguing for fossil fuels. The beginning of this conversation was pretty simple with both students stating their opinions without providing any justification and/or evidence for their statements (Lines 163 and 164). After the facilitator questioned the accuracy of Taishae's statement that fossil fuels did not harm humans (Lines 163 & 165), more productive student talk followed. The students began to elaborate more and started making valid points (166-173). For example, in line 170, Taishae brought up a good counter-argument against the facilitator's argument (Line 169) that the biomass usage was not a good choice. Although the facilitator did not admit it, Line 170's counter-argument seemed to make her rethink about her initial position regarding the biomass usage. Likewise, it made her think about alternative energy sources instead of cutting down trees (Line 171).

Day 4 - Fragment 3

(184) Barbara: *So, when it comes down to you, would use fossil fuels?*
(185) Taishae: *Yes*
(186) Chelsea: *Why?*
(187) Taishae: *Because fossil fuels, they damage the ozone whatever, layer, so does biomass. But, if you are taking trees, you are removing oxygen.*
(188) Chelsea: *OK, you stated that fossil fuels damage ozone layer…*
(189) Taishae: *So, the biomass.*
(190) Chelsea: *You said it that?*
(191) Taishae: *Yes…*
(192) Chelsea: *OK, if we continue using fossil fuels, what… we would be…*
(193) Taishae: *Yeah, but so biomass does it too, if you burn trees*
(194) Chelsea and Maria together: *Yes, but slowly*
(195) Taishae:*But it is still damaging…*
(196) Maria *It is damaging but slowly*
(197) Taishae: *You are loosing oxygen too, because you are cutting down trees*
(198) Chelsea: *If we continue using fossil fuels they are going ran away.*
(199) Taishae: *Not really. How long we have been using fossil fuels?*
Silence…
(200) Chelsea: *Like…*
(201) Taishae: *A lot of years, right? It is not ended*
(202) Chelsea: *Not yet. So, you do not like biomass, because it harms animals, but you are gonna use fossil fuels…*
(203) Taishae: *Not just animals. If you take away animals and*
(204) Chelsea: *Yes, we depend on animals too.*
(205) Taishae: *Not just the animals though. If bigger animals depend on smaller animals and bigger animals starve, and then, if big animals starve…*

(206) Chelsea: *Yeah, but if you use fossil fuels, its going to harm the ozone layer anyway.*
(207) Taishae: *Yeah, but if you are harming the ozone layer with biomass, I think you are limiting the oxygen level because you are cutting trees; it's like two things that impact life. Not just animals and humans.*
(208) Chelsea: *I disagree.*
(209) Taishae: *Of course you disagree, because you want to be right. But you are not right.*
(210) Chelsea: *I am right*.
(211) Taishae: *No, you are not*

Although this passage has demonstrated that Taishaewas knowledgeable about the ecological significance of interdependence (Lines 203, ,205 & 207), it was evident from the transcription that both the Chelsea and Taishae had misconceptions about the connection between burning of the fossil fuels and damaging of the ozone layer (Line 187, 206 & 207). It was obvious that students either were not aware of or got confused that burning fossil fuels had no impact on the ozone layer, but rather it created pollution in the troposphere. The depletion of the ozone layer was caused by the release of certain chemicals, such as CFCs, to the atmosphere. Another evidence against this misconception would be that while we continue using fossil fuels more extensively nowadays than 30 years ago, the ozone layer seemed to recover significantly during recent decades. Taishae brought up a point that cutting down trees was not a good idea since it would decrease the level of oxygen (Line 197). The facilitator rebutted this argument by providing a counter-argument that the dependence on fossil fuels was not a good idea either since we would eventually ran out of them (Line 198). Taishae rebutted the facilitator's counter-argument by stating that we had been using fossil fuels for a long time yet we had not run out of them yet (Lines 199 & 201). The facilitator could have argued against this faulty assumption by providing a scientific explanation about the formation of fossil fuels. Nevertheless, she just shortly answered "not yet" and shifted the conversation toward Taishae's other argument (Line202). Although the friendly environment was apparent in this group throughout all four days, the last dialogue between the facilitator andTaishae showed that the whole point of argumentation was "being right," "being a winner" (Lines 208, ,209 ,210 & 211). This passage has demonstrated that although students were highly respectful to each other, their arguments were directed toward each other rather than at each other's ideas. A similar phenomenon was not observed before.

Day 4 - Fragment 4

(221) Chelsea: *Basically any resource you use it's slowly killing*
(222) Taishae *I do not know about solar power though, because I do not how that harms anything. The sun is energy source; we use it anyway.*
(223) Chelsea: *Yes, we use it all the time, every day. But majority of resources we use harm the air as much as (inaudible)*
(224) Taishae: *But if you harm the air and we cut down trees, you are limiting oxygen. So we are doing two things harmful. But if just damage the air with air pollution, is OK. But if you are using biomass, damaging air, cutting down trees and lessening oxygen…*
(225) Chelsea: *What do you mean it is OK?*
(226) Taishae: *With the biomass you are harming the air and you lessen oxygen, because you cut down trees.*

(227) Maria: *He got his points…*
(228) Chelsea: *No, I disagree with that.*
(229) Taishae: *Why?*
(230) Chelsea: *I would use biomass; you can use your fossil fuels.*
(231)nTaishae: *Ok, think in this way. If you are using fossil fuels, right, you are damaging the ozone layer, right? And that is bad. But if you are using biomass you are damaging ozone and that is bad, but you are limiting oxygen because you are cutting down trees.*

In Line 221 Chelsea made a general statement that "any resource you use is slowly killing." Taishae subtly objected to Chelsea's generalization by saying that he was not sure about the solar energy meaning that he was not convinced that the solar energy had any harmful effects (Line 222). Chelsea backtracked from his initial statement and, essentially, agreed with Taishae's objections (Line 223). The rest of this conversation was very similar to previous conversations. It seemed that both students did not change their perception about the usefulness of a biomass; moreover, they stayed pretty firm in their beliefs. A couple of questioning techniques utilized by Chelsea and Taishae made the scientific talk more productive (Lines 225 and 229). In this fragment Taishae provided valid evidence and reasoning for supporting his claim. His argument was that by using biomass, we were not only polluting the atmosphere (just like with fossil fuels), but we were also decreasing the levels of oxygen (Lines 224,, 226 & 231). In this short fragment, Taishae seemed more passionate about his claim whereas the facilitator wanted to maintain her claim without providing any supporting data (Line 230).

Day 4 - Fragment 5

(300) Chelsea: *Actually, it is a healthier gas*
(301) Taishae: *Just because it is healthier air, it does not mean it is healthy in general*
(302) Chelsea: *Yeah, it does not mean it is healthy in general. It is healthier than fossil fuels.*
(303) Taishae: *How is it healthier to humans but yet like all the other things you are doing not just about… would not be?*
…………….
(304) Maria:
The prices are gonna go high
(305) Taishae: *They gonna rely more one corn and then they need to grow it*
(306) Barbara: *It's gonna get higher*
(307) Chelsea: *I think it would be in demand*
(308) Chelsea: *If we depend on corn, corn will be in demand, we even may ran out*
(309) Taishae: *Of course you are going to ran out, because you can not plant corn all year around, unless you are doing it not naturally.*
(310) Taishae: *It will cost more*
(311) Maria: *It will cost higher, the cost will be average until the corn will be decreasing and will cost more*
(312) Maria: *Oh, we talked for about 40 minutes*
(313) Taishae: *I win*
(314) Chelsea: *No, you did not*

Some students were able to employ counter-arguments very effectively, without any training or help provided by the researcher (Line 301). This explanation contains a reasoning component. It showed that scaffolding was an important pedagogical strategy that needed to be implemented in any lesson. When students were left on their own, even though they got engaged in a great conversation, they were focused on just cutting trees as a biomass source. But biomass is not just about wood; it is also about dung, methane generated from decomposed organic wastes, and ethanol as a source of gasohol. When students' attention got shifted from wood to other biomass sources, students were able to generate explanations and predictions about them (Lines 304-311). Some explanations contained a valid reasoning (Line 301), and some provided explanations included both an evidence and reasoning (Line 309). There were explanations where students used scientific predictions in order to explain their proposed scenario (Lines 304,, 305, 306, 307, 309, 310, and 311).

APPENDIX C

Student	**Total number of questions**	**Total number of lower level questions**	**Total number of higher level questions**	**Total number of procedural questions**	**Total number of clarifying questions**
Chelsea (F)	23	5	13	1	4
Maria	2	1	0	0	1
Jeremiah	3	1	0	0	2

Table 1 (Day 1)

	Lower Level Questions		**Higher Level Questions**			
Student	**Total number of remembering questions**	**Total number of understanding questions**	**Total number of applying questions**	**Total number of analyzing questions**	**Total number of evaluating questions**	**Total number of creating questions**
Chelsea (F)	3	2	0	3	10	0
Maria	1	0	0	0	0	0
Jeremiah	1	0	0	0	0	0

Table 2 (Day 1)

Student	**Total number of questions**	**Total number of lower level questions**	**Total number of higher level questions**	**Total number of procedural questions**	**Total number of clarifying questions**
Chelsea (F)	33	2	21	2	8
Maria	8	1	2	1	4
Barbara	5	0	4	0	1
Taishae	28	4	13	0	11

Table 3 (Day 4)

	Lower Level Questions		**Higher Level Questions**			
Student	**Total number of remembering questions**	**Total number of understanding questions**	**Total number of applying questions**	**Total number of analyzing questions**	**Total number of evaluating questions**	**Total number of creating questions**
Chelsea (F)	**1**	**1**	**1**	**4**	**14**	**2**
Maria	**1**	**0**	**0**	**1**	**0**	**1**
Barbara	**0**	**0**	**0**	**1**	**1**	**2**
Taishae	**4**	**0**	**0**	**4**	**8**	**1**

Table 4 (Day 4)