Why is the Quality of Discourse Important and How to Cultivate an Effective Learning Environment in STEM classrooms?

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Abstract

This literature review speculates that the quality of discourse in a STEM classroom is important because it can have a significant impact on students’ motivation, engagement, and achievement.

Teaching and learning invariably involve talking and listening. It is therefore obvious that the quality of classroom discourse should influence the quality of learning. But is this influence significant? This paper speculates that the quality of discourse in a STEM classroom is important because it can have a significant impact on students’ motivation, engagement, and achievement. This paper discusses how classroom discourse may help or hinder teachers in improving STEM instruction. Since discourse’s impact varies greatly depending on its nature and quality, the paper discusses traditional and non-traditional classroom discourses.

Keywords: IRE, argumentation, PBL, STEM instruction

“It’s important that we approach STEM not just as a subject, but as a mindset.”

~Camsie McAdams,
Director of STEM curriculum, Discovery Education

Current trends in education put heavy emphasis on learning and applying STEM concepts, as well as on effective pedagogical practices that increase student motivation in STEM subjects (McDonald, 2016). STEM-related competencies include important and necessary skills such as real-world problem solving, collaboration, critical thinking, and researching. Applying the STEM approach to education helps students learn that these skills can be utilized for a lifetime and that they are required for the 21st-century workforce. In addition, students develop deep scientific and mathematical knowledge. Since STEM education helps our students become successful citizens in the current competitive and globalized world, the National Science Foundation (NSF) provides several programs for increasing retention and graduation rates in STEM education, likewise improving the education of future scientists and engineers. In order to teach our students meaningful STEM lessons, we need effective STEM teachers who foster effective learning environments in STEM classrooms.

The aim of this paper is to advocate for STEM teachers to reflect on their teaching practices as they relate to the classroom discourse and the use of various teaching strategies that promote high-quality discourse. The paper considers a number of both traditional and contemporary teaching methods that promote meaningful discourse.
Classroom discourse analyses provide invaluable information not only on student learning, but also on teacher-student and student-student interactions that take place in the classroom (Woodward-Kron & Remedios, 2011). In her book *Classroom Discourse*, Cazden (2001) argued that the IRE (teacher Initiation, student Response and teacher Evaluation) is the most common discourse pattern across all subject areas and grade levels. She also claimed that the IRE is a default pattern of classroom discourse that flows naturally during the teaching practice (McNeil & Pimentel, 2010; Scott, Mortimer, & Aguilar, 2006). Does the IRE promote or hinder student learning? Since teachers ask questions that test student knowledge rather than foster student thinking in the IRE, many researchers maintain that the IRE does not do a good job in promoting student learning because, as they claim, actual learning can take place only when learners, not teachers, formulate their own questions (Alemeida, 2010; Blachowicz & Olge, 2008). It should be noted that not all researchers agree with this statement. Indeed, despite the criticism toward the IRE (Cazden, 1986), certain researchers tried to propagate the positive impact of the IRE on student learning (Lee, 2007; Zemel & Kischmann, 2011). For example, Zemel & Koschmann’s (2011) study demonstrated that the tutor’s consistent avoidance in providing explicit evaluations to students left students wondering whether their answers were insufficient. Students, thus, looked for refinements in their answers.

In addition, some educational researchers (Wells & Arauz, 2006) promote the IRF (initiation, response, and feedback) and highlight its advantages in classroom discourse. The IRF is similar to the IRE; the only difference is the last step, in which the teacher provides feedback as a result of inquiry practice. The IRF is considered better educational practice than the IRE because the last move, the follow-up step, is not considered pure evaluation (Sinclair & Coulthard, 1975). When the follow-up move is used appropriately in the last step, it can create a productive conversation between the teacher and the learner in the form of a dialogic stance (Wells & Arauz, 2006). This happens when certain patterns of conversation open up more avenues for productive discourse where various opinions and decision-making strategies are addressed (Juzwik, Borsheim-Black, Caughlan, & Heintz, 2014). There is an even more complex form of the IRF called IFRFRF (Mortimer & Scott, 2003), in which the teacher’s provided elaborated feedback is followed by student response.

Due to researchers’ skepticism towards the IRE, various alternatives were suggested with the assumption that they should lead to better educational outcomes. For instance, Cazden (2001) suggested that an alternative of the IRE could be integrated into the teaching practice, which could lead to significant social-cognitive changes in student learning. Likewise, many researchers claimed that alternatives to IRE could increase student motivation and student learning (Edwards & Mercer, 1987; Vaish, 2008). The alternatives to the IRE were explored in studies conducted in various STEM fields: mathematics education (Boaler, 2008; Chapin & O’Connor, 2007; Smith & Stein, 2011), science education (Driver et al., 2000; Mercer et al., 2010) and art and language education (Leung & Mohan, 2004; Nystrand, 2006). All the above-mentioned studies demonstrated that more purposeful discourses could help students express their thoughts more clearly and likewise make their talk and learning more productive.

Today, non-traditional classroom discourses have become increasingly popular and widespread. Instructional strategies such as PBL (Problem-Based Learning) and argumentation are very useful vehicles for engaging learners in meaningful, authentic, and practical discourse. Although classrooms are complex social systems (Cazden, 2001), they are also places where students do their business by constructing and reconstructing the meaning of their own learning. In addition, when students are engaged in argumentative discourse, they practice their reasoning skills, rather than relying on memorization and recitation (Andriessen, Baker, & Suthers, 2003).

Non-traditional classroom discourses and their constituent activities are becoming increasingly important in formulating the latest educational standards. For example, one of the objectives of science education’s recent shift is the advancement of robust science learning by student engagement in the critical thinking process through asking higher-level thinking questions and using evidence for responding to those questions (NGSS, 2013). The convergence of Common Core State Standards and Next Generation Science Standards will help students to prepare for the next generation’s workforce. Skills like collaboration, problem-solving, decision-
making, critical thinking, providing valid arguments, evaluating, and judging makes student discourse more productive and captivating in school settings. These are also the skills that students can carry with them beyond school. Mastering these skills during the students’ school years will be a beneficial educational experience, as it will enhance students’ college and workforce readiness.

Since non-traditional classroom discourses hold a promise of being significantly better than traditional ones, this paper will discuss some of the learning strategies in more detail to demonstrate their significance in student learning and achievement. Moreover, research recommends that teachers implement a student-centered approach, one which will make them focus on student thinking and student learning, rather than on covering the curriculum and following classroom routines (Levin, Hammer, & Coffey, 2009). Moreover, this kind of approach aids in developing students’ 21st-century skills, as well as mastering students’ STEM knowledge (Keiler, 2018).

**Problem Based Learning (PBL)**

Problem-based learning is one of the pedagogical strategies that fall under the umbrella of constructivism (Hmelo-Silver et al., 2007; Kuhn, 2007; Vogel-Walcutt et al., 2011). PBL is a useful pedagogical approach that not only helps learners deepen their conceptual understanding through solving ill-structured problems, but that also prepares learners in becoming independent problem solvers through inquiry and collaboration (Hmelo-Silver, 2004). Although PBL was initially implemented in medical schools where medical students were required to solve a variety of problems based on the medical hypothetical situations, this methodology can be easily used in any grade level and in any domain (Barrows, 2000). Moreover, this practice will eradicate boring memorization and will replace it by analyzing and evaluating the project’s underlying problems, which will help students come up with appropriate solutions. While examining the advantages of PBL, Hmelo-Silver (2004) emphasized the positive educational outcomes of PBL on overall student learning. For example, she determined that students who are engaged in PBL are better problem-solvers because they practice their knowledge of the content and brush up their thinking skills at the same time. During problem-solving, students are usually occupied with high-level and creative thinking processes, which, in turn, promotes students’ flexible thinking. The problems that students encounter in PBL projects elicit intrinsic motivation through complex and open-ended, real-world problems that can have more than one solution (Hmelo-Silver, 2004).

Collaborative learning becomes suitable in this situation, as it helps students tackle the problems collaboratively, rather than individually (Speck, 2003). In addition, PBL’s ill-structured schema allows students to gain skills that are vital for the 21st-century workforce (Baron, 2000). Furthermore, students find PBL interesting and get engaged easily, because they are already intrinsically motivated (Hmelo-Silver, 2004).

PBL organized for elementary school children (Mitchell et al., 2009) allowed students to communicate while providing non-judgmental feedback. This process not only invokes the reasoning of the young mind but also produces a productive discourse. In addition, the research demonstrated that students who were engaged in the PBL environment were much more able to transfer their knowledge to new tasks than students who were placed in traditional learning settings (Hmelo & Lin, 2000).

PBL’s productive discourse leads to the development of logic and problem-solving skills. Furthermore, science is considered an important factor in students’ daily life, contributing to the improvement of the quality of their life. Moreover, the use of PBL in mathematics classes helps students in making cognitive gains in mathematics. After all, “... the entire population is now deemed to be in need of significant mathematical power” (Kaput, 1992, p. 518). By connecting science to students’ real-life and engaging them in modern world applications, in which students receive opportunities to tackle real-world problems, teachers can increase student engagement and motivation and make learning more meaningful for them. PBL in science is an effective pedagogical approach that makes learning visible for students and assists them in learning how scientists approach. Furthermore, problem-based STEM approaches have been investigated through research and were improved via university-based professional developments (Asghar et al., 2012).

PBL also contributes to a better quality of discourse. One of the numerous advantages of PBL is that learners
get opportunities to plan, research and reflect on their own formulated and designed experiments, rather than replicating someone else’s experiment (Resnick & Ocko, 1991). Question formulation can be conducted as a separate inquiry practice for knowledge construction, or it can be utilized as a part of PBL. For instance, Clark (2006) proposed that students can develop their own questions as a part of project planning. Moreover, students in this study were asked to make hypotheses and predictions, use their imaginations and create representations of their findings, which created a dynamic learning environment. Teaching and learning science is not only centralized about delivering and learning science content. Current science standards require that students conduct investigations, construct and revise models, gather and analyze data, provide scientific explanations based on evidence, engage in scientific argumentation, ask critical questions and solve real-world problems (American Association for the Advancement of Science [AAAS], 2009; National Research Council [NRC], 2012; Next Generation Science Standards, Achieve, Inc. 2014). Therefore, STEM teachers should develop innovative strategies that will elicit their students’ scientific reasoning (Barnhart & van Es, 2015), leading to improved STEM education.

**Argumentation**

The term “argumentation” does not mean debate, although the debate is a form of argumentation (Nussbaum, 2011). Argumentation, which promotes learning (van Amelsvoort, Andriessen, & Kanselaar, 2007), is referred to as the process of constructing student artifacts (Sampson & Clark, 2008) and is also considered a form of discourse that needs to be explicitly taught to students via modeling and structured instruction (Mason, 1996). Moreover, argumentative discourse is a very important aspect of scientific knowledge in terms of science learning, (Kelly & Chen, 1999; Schwarz, Neuman, Gil, & Ilya, 2003) because it engages students in complex scientific tasks (Berland & McNeil, 2010) and enables them to be engaged in knowledge construction (Duschl, 2000) and in the understanding of science practices (Duschl, 2008). Enduran et al. (2004) utilized TAP (Toulmin’s Argument Pattern), which acts as a cognitive schema (Ryu & Sandoval, 2012), in order to analyze argumentation discourse in science classrooms in which the nature of the argument is framed as consisting of claims, data warrants, backings, and rebuttals.

In order to engage students in a deeper understanding of science content, Krajcik, McNeill, and Reiser (2008) utilized student-focused teaching methodology through the IQWST (Investigating and Questioning our World through Science and Technology) project. Effective teaching methods incorporated into the learning-goals-driven design model (Krajcik, et al., 2008) allowed students to engage in science practices, including argumentation, explanation, and scientific modeling. This approach leads to more productive discourse and student learning whereas the traditional curriculum places heavy emphasis on memorization and recitation (Kesidou & Roseman, 2002). Likewise, learners’ reflective thinking skills can be positively changed when students are introduced to the STEM integrated argumentation based science learning ABSL approach (Gulen, 2018).

Reflective practice may provide teachers with new ideas about enhancing students’ learning and understanding (Schulz & Mandzuk, 2005). Engaging in this practice is crucial, especially for novice teachers whose excessive focus on classroom procedures, such as raising hands and daily routines, may make them incorrectly believe that students learned the lesson material (Star, Lynch, & Perova, 2011). Likewise, teachers need to develop authentic interactions with their students during the discourse in order to enhance STEM learning (Wang, 2019). Past research showed that learners were not always productive in analytical discourse (Murphy, 2004). A good quality discourse may open up new avenues for students in expressing their own opinions, ideas, and suggestions and help them to go beyond the textbooks and worksheets. The most common discourse procedure used in the classrooms, the IRE, may lead to a low-quality talk and impede students’ progress in areas of problem-solving, questions asking, and solutions evaluation (Mehan, 1979). That is why it is recommended to create classroom environments where students are engaged in high-level discourse.

Engaging in scientific argumentation is one of the ways to improve the quality of discourse. Research in scientific argumentation has expanded in the past twenty years (Sampson & Clark, 2008). As an inquiry practice, scientific argumentation is increasingly seen in many science classrooms (Berland & Reiser, 2011).
Furthermore, with schools embracing technology, it becomes increasingly common to use computer-supported argumentation-based learning. CABLE (collaborative argumentation-based learning) is an example of this type of learning and has become very common in the Netherlands (van Amelsvoort et al. 2007). Research shows that engaging in argumentation increases student learning and reasoning (Baker et al. 2003; Kuhn et al. 1997). Unfortunately, students do not engage in argumentation naturally and, when they do, they frequently struggle with it (Ryu & Sandoval, 2012). Very often, students do not see the need and value of argumentation (Berland & Reiser, 2009), become reluctant in discussing contradictory issues (Lai, 2006), do not provide appropriate data to support their claims (Ryu & Sandoval, 2012) or may use insufficient evidence to back their claims (Sandoval & Millwood, 2005). For these reasons, the teacher plays a significant role in the successful use of argumentation in the classroom. In constructivist-based classrooms, students developed skills and confidence that helped them overcome and master ill-structured real-world problem-solving challenges (Hew & Knapczyk, 2007; Palincsar & Brown, 1984). This compares greatly with traditionally taught classrooms, in which students did well on tasks that required memorization of vocabulary words or processes but failed when they were asked to apply their newly learned material to a novel situation and/or in a real-life context (Lord, 1999).

Another key contributor to a good-quality discourse is the nature of tasks, as the research showed that open-ended, authentic problems could make room for more justifications and, therefore, for stimulating thinking (Almeida, 2010) and question asking (Tan & Seah, 2011). To foster online peer questioning, instructors and teachers can use modeling strategies and thinking skills (Schoenfeld, 1985) through question prompts (Choi, Land, & Turgeon, 2007). Furthermore, teacher’s involvement through scaffolding and modeling, teacher-generated challenging questions, and providing opportunities for students to elaborate and reflect on their thinking can foster deeper cognitive learning (Gerber et al., 2005; Hew & Knapczyk, 2007).

It should be pointed out that although scientific argumentation and scientific explanation are important components of the practices of science, some researchers argued that the terms have overlapping meanings (Berland & McNeil, 2012; Osborne & Patterson, 2011). However, others (Berland & Reiser, 2009) claim that explanation is the outcome or the by-product of argumentation. Three goals of scientific explanations are identified: sense-making, articulating, and persuading. Although each goal is important for student learning, the sense-making discourse will be useful for the conceptual challenge, whereas persuasive discourse may contribute to the changes in teacher-student interactions (Berland & Reiser, 2009). In shaping the study of argumentation through the lens of a structure of argument, researchers conducted studies about argumentation in conversation (Kelly, Druker, & Chen, 1998) and in writing (Bell & Linn, 2000) separately. Most of this argument analysis relied on Toulmin’s (1969) framework in the form of claims, data, and warrants. These studies allowed researchers to understand the structure of arguments taking place in classrooms and implications with respect to inquiry-based instruction.

Lastly, the proponents of scientific argumentation highlight differences between scientific and non-scientific argumentations. During scientific argumentation, discourse is driven by the learning, sharing, and processing of ideas. Winning the argument and disagreeing with a person are quintessential characteristics of non-scientific argumentation (Schweingruber, Shouse, & Michaels, 2007). Scientific argumentation promotes high-quality discussion by allowing students to review and apply their arguments to appropriate situations and communicate their arguments with others (Schweingruber, Keller, & Quinn, 2012). “Engaging in argument from evidence” is one of the Next Generation Science Standards (NGSS, 2013), and is closely related to another NGSS: “Asking questions and defining problems.” Argumentation is necessary in our classrooms to allow students to think and communicate like scientists.
Figure 1 highlights the shortened key aspects of PBL & argumentation in STEM classrooms.

Fig. 1. PBL & Argumentation in STEM classrooms

Conclusion

The quality of discourse in a classroom has become much more important nowadays than ever before. Indeed, the Project 2061 claimed that most Americans are scientifically illiterate (AAAS, 1989). Student engagement in high quality discussion in science context will improve scientific literacy because students will be practicing skills such as collaboration, argumentation, generation of higher-level thinking questions, construction of scientific explanation through evidence and reasoning, problem solving, decision making and other tasks that are culturally relevant to their lives. The above-mentioned skills will not only engage students in high level science classroom discourse, but will improve scientific literacy and produce more scientifically literate citizens for the future workforce.

Due to the importance of good quality discourse in STEM classrooms, it will be beneficial to reduce the use of the IRE in the classrooms since it does not provide opportunities for students to critique and comment on each other’s thoughts or express their own voice (Wood, 1992). The IRE discourse pattern works well with checking students’ prior knowledge but not the students’ complex reasoning. Moreover, when students get used to “expect” and “accept” discussion formats, the introduction of different discussion patterns may become difficult, at least at the beginning (Schweingruber, Shouse, & Michaels, 2007). STEM teachers are advised to avoid direct instruction and lecturing but rather focus more on student generated, evidence-based explanations (Driver et al., 2000; Duschl & Osborne, 2002). Therefore, it is recommended to integrate the alternative teaching strategies in classrooms in students’ earlier years. The strategies like PBL, collaborative learning, and good questioning promote high quality discourse and give students opportunities to think outside of the box, re-construct their knowledge, improve their understandings, and be engaged in high level, exploratory talk. This would lead to better student learning and achievement and prepare them for the real-world workforce.

This paper explored and recommended powerful teaching strategies for STEM teachers. It is recommended that STEM teachers choose one approach at a time, utilize it for one year and reflect upon the results. Whether their implemented strategy worked or not can be understood by conducting classroom action research, an excellent method for measuring the efficiency of teaching strategies (Mettetal, 2012). Therefore, good teaching begins with choosing and implementing an innovative teaching methodology, followed by conducting action classroom research, which evaluates the effectiveness of the implemented approach. The process concludes with critical reflection, allowing STEM teachers to reveal the strengths and weaknesses
of their own practice. The completion of this cycle aids STEM teachers in making decisions regarding their teaching style and, most importantly, maximizes student learning.

References


