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Organizational perspectives on co-teaching triads participating in a science and engineering professional development program

by

Christopher D. Spinler

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Science Education

Program of Study Committee:
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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University
Ames, Iowa
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The final word of thanks is reserved for my mother, last not because she is least, but because without her generous and grandmotherly support, none of this would have been possible.
Co-teaching triads composed of grades 3-5 cooperating/student teacher dyads and an engineering graduate student were formed; triads met once per week to collaboratively plan and implement science and engineering lessons. Sharp distinctions in elementary school classroom teaching experience and knowledge of science and engineering content were present in these triads. The purpose of this dissertation was to better understand how participants’ educational and professional backgrounds interacted in the context of the classroom.

Research on co-teaching dyads may inform studies of the performance and relational aspects of co-teaching triads, but may not be fully capable of addressing the potential complexities related to three-person group dynamics and asymmetries in distribution of knowledge and skill. In the first study, literature from the areas of research in co-teaching and small group dynamics was synthesized to create a conceptual framework for understanding the nature of co-teaching triad structure and tasks and internal and external factors that may impact triad performance.

The second study investigated the roles played by members of the science and engineering co-teaching triads using a multiple case study approach. Data for this study was collected in participant interviews and during observations of collaborative planning meetings and co-taught lessons. Results of this study indicate that triad members took on roles related to their identity within their triads. Conflicting understandings of the role of teachers and content knowledge in elementary science and engineering education may have led to role conflict in some triads. Further, opportunities for participant professional growth may have been impacted by the unique composition of the triads.
The final study investigated the team effectiveness of the co-teaching triads. Team effectiveness is a multi-dimensional construct reflecting the degree of performance quality achieved by a team and team member attitudinal and satisfaction-related perspectives. Specifically, this study operationalized team effectiveness as triads’ composite scores on a science lesson evaluation instrument and aggregated triad member satisfaction ratings related to triad lesson planning and implementation activity. Results indicate that triad team effectiveness was impacted by the extent to which triads engaged in surfacing student prior knowledge, use of evidence, and sense making of targeted ideas.
CHAPTER 1. OVERVIEW OF RESEARCH PROBLEMS

Challenges Present in Elementary Science and Engineering Education

In the past, K-12 engineering education has received little public attention (Katehi, 2014) beyond elective courses and after-school programs at the secondary level, but with the introduction of the Next Generation Science Standards (NGSS), engineering has become an important component within both elementary and secondary science education. At the elementary level in particular, engineering education is a recent phenomenon (Katehi, 2014). In spite of its newness, however, research indicates that elementary engineering education may provide benefits for students, including improved outcomes in reading and mathematics (Katehi, 2014), increased technological literacy (Gattie & Wicklein, 2014), and experience with problem-solving in real-world contexts (Moore, Tank, Kersten, & Smith, 2014).

Elementary teacher preparation to teach science has been a subject of enduring concern (Davis, Pettish, & Smithy, 2006), and the integration of engineering education into elementary science standards introduces additional complexity to elementary science teacher preparation. Cunningham and Carlsen (2014) note that elementary teachers receive little exposure to engineering during their K-12 educational experience, while Nadelson and Farmer (2012) write that engineering coursework is infrequently included among elementary teacher preparation requirements. Further, Lambert et al. (2007) found that elementary teachers frequently hold mistaken conceptions of engineers and the work they do. Not surprisingly, Banilower et al. (2013) report that two-thirds of K-5 teachers feel inadequately prepared to teach engineering, and only 1% had taken any engineering coursework. Content knowledge is known to impact teachers’ ability to teach specific subjects (Horizon Research, 2010); as such, teachers that are
uncomfortable with engineering may encounter difficulties when required to teach it (Brophy et al., 2008).

**Science and Engineering Professional Development Programs**

Professional development programs emphasizing engineering content may help mitigate the challenges teachers face with regard to science and engineering education (Webb, 2015). Teacher professional development has been shown to improve teaching practices when focused on delivery of content to students, student behavior, solicitation of student engagement, and surfacing student thinking (Kennedy, 2016), areas in which elementary teachers often encounter challenges (Banilower et al., 2013; Van Haneghan, Pruet, Neal-Haltman, & Harlan, 2015). An example of a science and engineering professional development program designed to address these issues is the National Science Foundation’s Graduate STEM Fellows in K-12 Education (GK-12) initiative. GK-12 was a nationwide STEM professional development initiative pairing science, technology, engineering, and mathematics (STEM) graduate students with K-12 classroom teachers to assist in planning and teaching science, mathematics, and engineering lessons (Brewer et al., 2013). Research from GK-12 programs indicates participating classroom teachers increased in STEM content knowledge, acquired new STEM pedagogical techniques, and gained confidence in teaching STEM subjects (Gamse et al., 2010; Mitchell et al., 2003), with improvement in teaching and communication abilities observed among graduate student fellows (Orr, Quinn, & Rulfs, 2007).

**Trinect Program**

A professional development program similar in approach to GK-12 is Trinect. The Trinect program is an NSF-funded science and engineering education professional development initiative that blends the GK-12 classroom teacher-STEM graduate student partnership approach
with a student teaching placement. The Trinect model pairs an engineering graduate student (“engineering fellow”) with a grade 3-5 student/cooperating teacher dyad working in a large urban school district to form co-teaching triads. Engineering fellows spend one full school day per week in their assigned classrooms, where they work with the student/cooperating teacher pairs to implement the district’s science curriculum; the district has adopted NGSS and therefore expects engineering to be included in district science programs. Co-teaching triads work together for the duration of a 16-week student teaching placement. The engineering fellows participate for a full academic year, working with a different cooperating/student teacher pair each semester. Through sustained collaboration with a STEM expert, this approach may improve preservice elementary teachers’ ability to teach science and engineering while simultaneously serving as a medium for inservice teacher science and engineering professional development. Through their work with the cooperating and student teachers, engineering fellows may improve their teaching and communication skills and gain an appreciation for the complexities of teaching and learning.

Co-teaching

Trinect participants are tasked with planning and teaching lessons that support the district’s science and engineering goals. To accomplish this, participants engage in co-teaching. Co-teaching occurs when multiple teachers plan lessons, deliver instruction, and assess student work for a single group of students in one location (Cook & Friend, 1995; Murawski, 2003; Friend, Cook, Hurley-Chamberlin, & Shamberger, 2010). By combining individual knowledge and skill, co-teachers may create a learning environment substantively more rich than what could be achieved by a single teacher alone (Murawski & Lochner, 2011). While co-teaching as a strategy is often associated with special education (Badiali & Titus, 2010), its use as a medium
for pre-and inservice teacher professional development is not without precedent. Bacharach and colleagues have used co-teaching within preservice teacher education. In this approach, student teachers engage in collaborative planning, teaching, and assessment with their cooperating teachers; findings from their work indicate that co-taught field experiences benefit both student and cooperating teachers (Bacharach, Heck, & Dahlberg, 2008, 2010). Additionally, many of the GK-12 teacher-fellow partners were observed to engage in some form of co-teaching as well (Brewer et al., 2013).

**Challenges Related to Triad Co-teaching**

The Trinect approach thus represents an amalgamation of research-supported preservice and inservice co-teacher professional development practices. However, triadic co-teaching presents challenges not present in paired co-teaching arrangements. While balanced parity relationships between paired co-teachers are crucial to the health of a co-teaching partnership (Pratt, 2014; Pratt et al., 2017; Rice & Zigmond, 2000), between co-teaching pairs there is only a single relationship. Within Trinect co-teaching triads, however, three potential relationships exist, and each of these relationships has a difference in real or perceived social power. The actions of student teachers are known to be influenced by their desire to receive a positive reference from their cooperating teachers (Anderson, 2007). Triad engineering fellows are experts in a field of engineering and thus may be able to influence their teammates through recourse to their depth of content knowledge and experience; a similar effect may occur with respect to the cooperating teachers, whose experience with teaching in elementary school classrooms is likely more extensive than that of their teammates. These relationships may be further mediated by triad member personality characteristics. In three-person groups, differences in real or perceived social power are known to catalyze the formation of “two against one”
coalition sub-groups (Caplow, 1968). Thus, the potential exists that intra-group relationship dynamics may be more influential in Trinect co-teaching triads than in paired co-teaching relationships. Additionally, asymmetries with respect to content knowledge and pedagogical experience in Trinect triads may likely be more distinct than those present in a traditional paired co-teaching arrangement. While the individual areas of specialization may complement each other (McNeal et al., 2013), triad members must remain aware that perspectival differences with respect to the role of teachers and content knowledge attendant to individuals’ educational and professional backgrounds may degrade triad functionality unless identified and addressed.

**Efficacy of Research on Paired Co-teachers**

The Trinect approach to co-teaching offers potential benefits to students in terms of access to a science and engineering professional and the potential for increased teacher attention resulting from a reduced student-to-teacher ratio. In order for these benefits to be realized, however, triads must navigate potential challenges related to disparities in social power and imbalances in knowledge and experience. Findings from studies of paired co-teachers may be used to help triad members address these issues. For instance, the co-teaching literature makes quite clear that co-teachers both value and benefit from the availability of collaborative planning time and the efficient use of that time (Dicker & Murawski, 2003; Keefe & Moore, 2004; Kohler-Evans, 2006). Additional findings indicate that positive co-teaching outcomes may be facilitated by discussions related to individual perspectives on teaching, learning, and classroom management (Pratt, 2014; Rice & Zigmond, 2000). However, while some findings from studies of paired co-teachers may readily generalize to co-teaching triads, others may not. For example, Cook and Friend (1995) describe five instructional models frequently used by co-teaching dyads. Keely (2015) notes that the choices co-teachers make regarding which co-teaching model to use
may have implications for teacher self-efficacy and student learning. The co-teaching models used by three-person co-teaching groups, however, have not been studied, and the extent to which similar implications exist for co-teaching triads is unknown. Further, findings from studies of co-teaching dyads show that paired co-teachers value personal compatibility and harmonious personal and professional relationships (Hang and Rabren, 2009; Scruggs, Mastropieri, and McDuffie, 2007; Walther-Thomas, 1997). As described above, however, co-teacher relationships in Trinect co-teaching triads may be more likely to be influenced by disparities in social power, content knowledge, and pedagogical experience than those among co-teaching pairs. Thus, while findings from studies of paired co-teachers may inform the functionality of Trinect co-teaching triads, the distribution of triad member knowledge and experience in these triads makes *a priori* generalization of results somewhat problematic.

**Organizational Perspectives on Triad Co-teaching**

Studies of paired co-teaching arrangements may provide insight into the performance and relational aspects of Trinect co-teaching triads, but are not fully capable of addressing the potential complications related to three-person group dynamics and asymmetries in distribution of knowledge and skill. Theoretical and empirical frameworks that *do*, however, address these issues are found in the areas of organizational psychology and behavior. In particular, theories of work teams and teamwork may be used to (1) better understand the functioning of three-person co-teaching groups with disparities in knowledge and skill; (2) address possible contingencies related to these disparities; (3) optimize the performance and relational quality of three-person co-teaching groups. Trinect co-teaching triads exhibit the characteristics of work teams, and thus investigating triadic co-teaching from an organizational perspective is
appropriate. Aspects of organizational psychology relevant to Trinect co-teaching triads include *team effectiveness, team mental models, and team roles.*

**Team Effectiveness**

The *raison d’être* of work teams is to perform employment-related tasks; central to the investigation of work teams in any context is degree of performance quality reached by the team and the identification of factors and contingencies that may amplify or suppress team functionality. Studies of team performance are supported by the *functional perspective* of small group research (Poole et al., 2004); this perspective examines teams in terms of the factors that influence team performance and investigates the activities and behaviors that promote or detract from group effectiveness. The central function of any work team is to perform a task; teams that perform their tasks well are generally considered to be more effective than those that perform poorly. However, team members possess a variety of employment-related needs that elements of the team task and work environment may satisfy or frustrate. Members of teams which meet these needs are more likely to feel valued and respected within the context of the team, paving the way for further teamwork (West, 2012). On the other hand, members of teams that incite dissatisfaction or dissent may be less likely to work together harmoniously and may descend into open conflict. Thus, while teams need to accomplish their tasks with a high degree of performance quality, the team task and work environment must be such that they both promote and support positive member affect. This dual nature of team success is captured in the construct of *team effectiveness.* With respect to the notion of team effectiveness, performing the team task in an exemplary manner is not enough; in addition to high quality task performance, effective teams promote positive interpersonal relationships and individual satisfaction among team members. Assessing team effectiveness thereby requires both a set of criteria used to assess
quality of task performance and measures of the attitudinal and satisfactional disposition of team members. Examples of the former include managerial performance and customer ratings, while examples of the latter include team member satisfaction surveys and team member performance evaluations.

**Team Mental Models**

Assessments of team effectiveness coordinate outcomes of team task performance with measures of team member satisfaction and fulfillment; a great deal of research effort has been put forth toward identifying and maintaining factors that both promote and support effective teams. One such factor is the extent to which team members possess among themselves shared cognitive representations of the team task and environment. Called *team mental models*, these shared understandings include representations of tasks, equipment, team member relationships, and situations and contingencies and represent the conceptual and procedural knowledge needed to accomplish team goals (Mohammed & Dumville, 2001). Team mental models promote team effectiveness by helping to ensure that team members are “on the same page” with regard to who is responsible for particular sub-elements of the team task, which in turn promote efficient coordination of team member actions and improved communication. In addition, team mental models enhance team performance by reducing team member cognitive load (Mathieu, Maynard, Rapp, & Gilson, 2008; Stout, Cannon-Bowers, Salas, & Milanovich, 1999); team members may be more likely to perform their own tasks efficiently to the extent they are confident that their teammates will perform theirs. The formation of robust team mental models has been empirically linked to the extent to which teams engage in effective collaborative planning (Stout et al., 1999)
**Team member roles.** Team mental models help team members know what they and their teammates are to do with respect to performance of the team task. A process that is related to the formation of a team mental model is team member role adoption. *Roles* are typical sets of behaviors exhibited by individuals in a particular context (Levi, 2007). Within teams, roles help ensure that task behaviors are appropriately interrelated so that group goals may be accomplished (Johnson & Johnson, 2003). Two general categories of roles have been identified. *Task roles* relate to behaviors associated with accomplishment of the team task, while *relationship roles* support the socioemotional needs of and relationships between team members (Forsyth, 2014). Team effectiveness encompasses both task performance and team member satisfaction with team performance and member relationships; team effectiveness may be optimized when across the team, positive examples of both roles are represented. Investigation of team member roles is undertaken from the *conflict-power-status perspective* of small group research (Poole et al., 2004). This approach examines groups in terms of the dynamics of power, status, resources, and social relationships, and the group structures associated with these factors, focusing on the ways in which the differences in group member influence and specialization impact group activity.

**Overview of Dissertation Chapters**

**Organizational Aspects of Science and Engineering Co-teaching Triads: A Review and Synthesis of Literature**

Trinect co-teaching triads face both potentialities and pitfalls related to the nature of their composition. While literature related to co-teaching dyads may provide useful insight into the functionality of Trinect co-teaching triads, published findings are not sufficiently broad so as to capture all aspects of triad co-teaching. Conceptual and empirical frameworks that can accommodate the added complexity relating to three-person group dynamics and sharp disparities in group member knowledge and skill are found in the area of organizational
psychology and behavior. This paper, included as Chapter 2, reviews the literature surrounding co-teaching dyads and foundational concepts of teamwork theory. Key aspects from each are synthesized to form a conceptual framework that illuminates both the performance and relational aspects specific to Trinect co-teaching triads.

**Team Member Role Distribution in Science and Engineering Co-teaching Triads**

Distribution of task-related responsibilities is crucial in optimizing team performance and effectiveness. While role distribution between paired co-teachers has been studied in a variety of contexts (e.g., Bouck, 2007; Weiss & Lloyd, 2002), the roles taken on by members of co-teaching triads with disparities of knowledge, experience, and social power have not been studied, despite increased use of both co-teaching and involvement of STEM professionals in K-12 classrooms. This study, included as Chapter 3, examined the general and task-specific roles that were employed by Trinect co-teaching triads in both planning and implementation of science or engineering lessons. The distribution of observed and self-reported roles was considered both within and across triads.

**Team Effectiveness of Science and Engineering Co-teaching Triads**

Effective teams perform their assigned tasks in an exemplary manner while simultaneously maintaining an environment that promotes and supports positive team member relationships and satisfaction. In the context of Trinect co-teaching triads, effective co-teaching teams teach high quality science and engineering lessons while promoting positive team member satisfaction. This study, included as Chapter 4, seeks to identify what levels of team effectiveness were attained by triads in the Trinect project. This was accomplished by combining ratings of triad classroom performance and measures of triad member satisfaction.
This study provides insight on the effectiveness of using STEM professionals with preservice and inservice teachers as a professional development model.

**Implications and Further Research**

The fifth and final chapter of the dissertation places Chapters 2-4 in a larger context and addresses implications of this work as a whole for the field of STEM education research, including preservice and inservice teacher education efforts.

**References**


CHAPTER 2. ORGANIZATIONAL ASPECTS OF SCIENCE AND ENGINEERING CO-TEACHING TRIADS: A REVIEW AND SYNTHESIS OF LITERATURE

ABSTRACT

Research on co-teaching dyads may inform studies of the performance and relational aspects of co-teaching triads, but may not be fully capable of addressing the potential complexities related to three-person group dynamics and asymmetries in distribution of knowledge and skill. In this study, literature from the areas of research in co-teaching and small group dynamics is synthesized to create a conceptual framework for understanding the nature of co-teaching triad structure and tasks and internal and external factors that may impact triad performance.

Introduction

Co-teaching pairs have been well-studied and a great deal is known regarding how paired co-teachers work together to plan and implement collaboratively taught lessons. While some findings from research on paired co-teaching may generalize to Trinect co-teaching triads, others may not. Thus, the need exists for an analytical framework that can accommodate both the imbalance of pedagogical skill and content knowledge present in the triads and the attendant disparities in real and perceived social power. Given the relational structure of Trinect co-teaching triads, conceptual and empirical frameworks from the areas of organizational psychology and behavior represent appropriate points of view from which to view triad functionality. The purpose of this study is to synthesize findings from research on paired co-teaching and small group dynamics to form a unified conceptual framework through which to view the collaborative planning, lesson implementation, and assessment activities of Trinect co-
teaching triads. The large scale research inquiries guiding this inquiry were (1) In what ways are the instructional activities of Trinect co-teaching triads similar to and different from the activities of co-teaching dyads?; (2) In what ways are the instructional activities of Trinect co-teaching triads similar to and different from the activities of small work groups embedded in organizations?; (3) In what ways are the relational dynamics of Trinect co-teaching triad member relationships similar to and different from the relational dynamics of co-teaching dyads?; (4) In what ways are the relational dynamics of Trinect co-teaching triad member relationships similar to and different from the relational dynamics of small work groups?; (5) What factors support positive outcomes of paired co-teaching, and to what extent might these factors support positive co-teaching outcomes for Trinect co-teaching triads; (6) What factors support effective small work groups embedded in organizations, and to what extent might these factors support Trinect co-teaching triads?

**Co-teaching**

Co-teaching is the practice of two or more teachers sharing responsibility for the instruction of a single group of students; while its theoretical underpinnings trace their heritage to the practices of inclusive schooling, as a general practice co-teaching has been employed in a variety of educational settings. The research base surrounding co-teaching is expansive, with findings indicating that co-teaching may benefit general and special education students both socially and academically (Dieker, 2001; Walther-Thomas, 1997) and may further serve as a catalyst for teacher professional growth (e.g., Weiss & Brigham, 2000). As a general practice, co-teaching has been successfully implemented in literacy, mathematics, and science instruction (Brendle, Lock, & Piazza, 2017; Cacciato & Morey, 2017; Moorehead & Grillo, 2013) and has also found a home in pre-service teacher education in a variety of disciplines and contexts (e.g.,
Bacharach, Heck, & Dahlberg, 2010; DelColle & Keenan, 2015; Murphy, Beggs, Carlisle, & Greenwood, 2004). This section will review research related to co-teaching, highlighting the instructional practices used by co-teachers, research findings related to the efficacy of co-teaching as a practice, and the factors associated with successful co-teaching experiences.

As a practice, co-teaching traces its roots to the late 1950s, as reform-minded educators sought to increase individualized instruction to students during an acute teacher shortage (Friend & Reising, 1993). Interest in co-teaching was nominal until the 1980s, during which time an increased acceptance of the principles of inclusive schooling fostered the belief that special education could be delivered in a general education setting (Friend, Cook, Hurley-Chamberlin, & Shamberger, 2010). Two foundational pieces of legislation further increased interest in co-teaching, both as a practice of inclusive education and an object of research. The 1994 Individuals with Disabilities Education Improvement Act (IDEA) made explicit the expectation that students with disabilities would receive education with their non-disabled peers in the least restrictive environment available (Solis, Vaughn, Swanson, & McCulley, 2012). In 2001, the signing into law of the No Child Left Behind (NCLB) legislation expanded and reinforced this notion with the requirement that all students, regardless of disability status, receive their education from instructors who have demonstrated competence in all subject areas they teach; this expectation encouraged collaboration between content-area teachers and learning specialists (Thousand, Villa, & Nevin, 2006). Co-teaching has been widely studied, and while a shortage of rigorous research findings has caused some authors to withhold support for co-teaching as a research-based practice (Cook, McDuffie-Landrum, Oshita, & Cook, 2011; Volonino & Zigmond, 2007), co-teaching continues to be widely practiced in primary, secondary, and tertiary
education in the United States and internationally (Dugan & Letterman, 2008; Gable, Mostert, & Tonelson, 2004; Rice & Zigmond, 2000).

**Defining Co-teaching**

Numerous characterizations of co-teaching exist within the research literature; common to all, however, is the notion of two or more teachers combining knowledge, skills, and experience to deliver instruction to a single group of students. Frequently cited are Cook and Friend (1995), who define co-teaching as two or more professionals delivering instruction to a diverse group of students in a single physical space (p. 1). The work of Roth and colleagues frames co-teaching as a process of learning from an experienced other (e.g. Roth, 1998), emphasizing the co-generation of knowledge as teachers navigate and make meaning from educational situations. Co-teaching represents a shift of paradigm, moving away from an individual model of teaching toward a restructuring of teaching procedures that promotes collaboration between professionals whose knowledge and experience may differ (Bauwens & Hourcade, 1995). The practice of co-teaching is predicated on the notion that multiple teachers in a single classroom will reduce the teacher-to-student ratio, resulting in more individualized instruction, increased opportunity for students to respond, and enhanced classroom management (Sweigart & Landrum, 2015). While the proportion of instructional resources and effort exerted by each teacher may vary, through collaboration co-teachers create a learning environment not attainable by a single teacher (Friend, 2008); elements of collaborative learning environments that benefit students include teacher sharing of instructional responsibility, establishment of strong classroom communities, support for hands-on learning activities, and increased teacher attention (Pugach & Wesson, 1995). The goal of co-teaching is to create the most effective and
enjoyable learning experiences for students while simultaneously offering co-teachers the opportunity to learn from each other (Murphy & Beggs, 2006).

A full co-teaching partnership is one in which participant teachers jointly consider student learning goals and objectives, work together to plan lessons, employ paired co-teaching models to deliver instruction, and collaboratively assess student work (Murawski, 2003). In addition, co-teachers are held jointly accountable for their classroom and performance (Cook, 2004). Friend et al. (2010) reinforce this definition, describing an effective co-teaching relationship as one in which both professionals are actively involved in all aspects of the instructional process; co-teaching is not a “lead with assistant” arrangement in which one teacher delivers instruction while the other monitors student behavior, assists with classroom logistics, or supports only a single student (Dieker & Murawski, 2003). Cook and Friend (1995) write that while two adults may often be present in a classroom (e.g., parent volunteers), authentic co-teaching means that both are involved in substantive instruction of students. Co-teaching represents a committed and ongoing relationship that is more than an occasional sharing of instructional responsibilities with a teaching colleague (Cook, 2004). The need for close collaboration between co-teachers has led to frequent comparisons between co-teaching and a marriage (e.g., Kohler-Evans, 2006) or business partnership (Friend, 2016), with an emphasis on strong, parity-based relationships, equitable allocation of responsibilities, and effective conflict resolution skills (Scruggs, Mastropieri, & McDuffie, 2007). Villa, Thousand, and Nevin (2008) underscore this point, noting that co-teaching requires participants to agree upon instructional goals, share common systems of belief, and distribute leadership roles.
Overview of Research

Co-teaching has been widely studied across a variety of contexts. While some studies have been subject to concerns regarding reliability, methodology, and a paucity of empirical data (Cook et al., 2011; Volonino & Zigmond, 2007; Kloo & Zigmond, 2008; Muraswski & Swanson, 2001), results indicate that co-teaching may be a vehicle for improved educational outcomes for both special and general education students if enacted in accordance with research findings. Further, findings show that a collaborative approach may promote professional growth in both special and general education teachers.

**Student outcomes.** Co-teaching places two professionals in front of a single group of students for an extended period of time. This collaboration reduces the teacher-to-student ratio, provides students with access to the knowledge and experience of two teachers, and promotes a classroom atmosphere conducive to increased academic achievement and positive peer relationships. In a wide-ranging study of co-taught elementary classrooms, Walther-Thomas (1997) found evidence of increased student self-esteem and academic self-efficacy, improved academic performance, and enhancement of social skills and peer interactions among students with disabilities. Hang and Rabren (2009) report similar findings in a quasi-experimental study of co-taught elementary, middle, and secondary school classrooms. In a comparison of student performance prior to and after completion of an academic year in co-taught classrooms, the authors noted a significant increase in student reading and mathematics scores and report that students with disabilities felt better supported and learned more in the collaborative environment. Further empirical support for increased academic performance in co-taught classrooms was provided by Witcher and Feng (2010), who directly compared solo- and co-taught fifth-grade mathematics classes; although no significant differences were observed, results of the study
favor the co-taught approach. Findings supporting co-teaching as a vehicle for growth among students with disabilities were also reported by Pugach and Wesson (1995) and Conderman (2011), both of whom observed that students in co-taught classrooms showed increased academic achievement and an overall improvement in their school experience. Students taught by co-teaching pairs were further noted to have increased opportunities to respond to teacher inquiries and receive more one-on-one instruction and positive feedback in co-taught as opposed to solo-taught classrooms (Sweigart & Landrum, 2015). Although Hang and Rabren (2009) found an increase in student behavior issues, co-taught classrooms have been observed to tend toward a more easily managed atmosphere with fewer student disruptions and discipline referrals (Rice & Zigmond, 2000).

General education students may also benefit from co-teaching. Pugach and Wesson (1995) found that both general and special education students taught by co-teachers showed evidence of increased social and academic self-esteem and performed better academically. In her study of co-taught elementary classrooms, Walther-Thomas (1997) found that general education students increased in academic ability and benefited from the cognitive techniques (e.g., mnemonics) and study skills taught by special education teachers and from an overall emphasis on positive teacher and peer relationships. Additionally, students in both populations benefited from individual teacher attention, reduced student-to-teacher ratios, and observation of positive collaboration skills between co-teachers (Scruggs, Mastropieri, & McDuffie, 2007). Walther-Thomas, Bryant, and Land (1996) note that enhanced progress monitoring, individual assistance and opportunities for re-teaching are more easily facilitated in classrooms in which the student-teacher ratio has been reduced. Dieker (2001) writes that although some students may
not understand why there are two teachers in their classroom, all students benefit from increased academic assistance and fewer behavior problems.

While some studies report student gains in academic achievement, others have found that these improvements may not be long lasting. Kloo & Zigmond (2008) note that while students with disabilities did make significant improvements in class work, student scores on standardized tests did not correspondingly improve. Further, in a meta-analysis of 32 studies, Scruggs, Mastropieri, and McDuffie (2007) found that although co-teaching was held in positive regard by both students and teachers, a range of supports were required for co-teaching to be effective (Friend, 2008). Thus, while co-teaching does hold promise as means for enhancing instruction for both general and special education students, findings indicate that stakeholders in co-taught classrooms must work to ensure that the conditions and resources required for successful co-teaching are in place and that further research on the efficacy of co-teaching vis a vis student outcomes is conducted.

**Teacher professional growth.** Studies indicate that co-teaching may be an effective model for teacher professional development. Participants in co-teaching relationships have access to the knowledge and experience of another professional, and through this connection teachers may explore new content areas, learn new instructional strategies, and find increased job satisfaction. Walther-Thomas (1997) noted that elementary school co-teachers realized an overall increase in job satisfaction and teaching self-efficacy, were able to explore new content and pedagogical skills, and enjoyed access to the enhanced network of support provided by close collaboration with another teacher. In a multi-grade level study of co-teaching participants, Austin (2001) found that both special and general education teachers felt that their co-teaching experience was helpful to their teaching practice, citing the reduction of the teacher-to-student
ratio and access to the knowledge and experience of another as particularly beneficial. In a 2009 survey study of urban elementary teachers, Damore and Murray found that teachers working in co-taught classrooms held positive perspectives on the team processes involved in working with another teacher and valued the opportunities for shared responsibility, teacher communication, and professional growth. Teachers also held positive views of the impacts of co-teaching on student academic performance and social aptitude (Keefe & Moore, 2004; Rice & Zigmond, 2000).

**Research limitations.** In spite of its wide-spread appeal, research on co-teaching outcomes has been sparse (Friend et al, 2010). Incited by a “woefully inadequate” research base, Zigmond and Magiera (2001) issued a cautionary statement, stating that despite the intuitive appeal of co-teaching, the available research could not support the claim that co-teaching provides substantial academic advantages to students. That same year, a meta-analysis conducted by Murawski and Swanson (2001) found co-teaching to be a “moderately effective” practice in special education settings. Notably, however, out of 89 reviewed studies, only six contained enough quantitative data to warrant inclusion in their analysis. Kloo & Zigmond (2008) observed that much of the published co-teaching literature focused on logistics, descriptive studies, and recommendations, and called for an increase in scope and intensity of experimental studies of co-teaching. More recently, Cook et al. (2011) note that many studies of co-teaching lack literature-supported indicators of quality and rigor, and on this basis made the recommendation that co-teaching in special education settings not be considered an evidence-based practice.
Elements of Co-teaching

Murawski (2003) identifies three elements of the co-teaching process: co-planning, co-instruction, and co-assessment; authentic co-teaching requires the presence of all three elements (Murawski & Lochner, 2011).

Co-planning. Effective co-teaching is not spontaneous, but instead the result of dedicated and focused collaborative planning (Scantlebury, Gallo-Fox, & Wassell, 2008). Co-planning occurs when co-teachers jointly plan lessons, assign instructional roles and responsibilities, and discuss how student progress will be assessed. The ability to collaboratively plan instruction is crucial to co-teaching relationships and is frequently reported as one of the most important elements of a co-teaching partnership (Dieker & Murawski, 2003; Keefe & Moore, 2004; Kohler-Evans, 2006). Conversely, limitations on the ability to engage in collaborative planning have been a perennial concern among co-teachers (Dieker, 2001; Dieker & Murawski, 2003; Mastropieri et al., 2005; Pratt, 2014). Although co-teachers highly value co-planning, Pratt, Imbody, Wolf, and Patterson (2017) note that collaborative planning may be challenging to some co-teaching partnerships. Murawski & Lochner (2011) underscore the importance of co-planning, writing that unless co-teachers engage in joint planning, they are at best working together in a parallel manner (p. 2).

During collaborative planning teachers share experience and work toward agreements regarding what content will be taught and how roles, responsibilities, and effort will be allocated during instruction (Sileo, 2011; Tannock, 2009). In addition, co-teachers discuss what will occur during co-taught lessons, who will teach which components of the lessons, and which co-teaching models will be used (Pratt et al., 2017). Long range curriculum planning may also occur during collaborative planning meetings (Simmons & Magiera 2007). In order to
incorporate the experience and knowledge of each co-teacher, it is essential that both teachers contribute instructional methods, materials, and assessment practices (Conderman, 2011).

In a longitudinal study of elementary school co-teachers, Walther-Thomas (1996) found five themes among co-teachers who considered themselves effective co-planners. These themes were (1) trust in the professional abilities of co-teaching partners; (2) learning environments that promote active involvement in lessons for both students and co-teachers; (3) creation of learning environments in which student and teacher contributions are valued; (4) development of efficient co-planning routines; (5) refinement of co-planning skills over time. Collaborative planning may further be facilitated by online interactions, phone calls, and text messaging (Pratt et al., 2017).

Planning for co-teaching may also occur at the district and building level (Walther-Thomas, Bryant, & Land, 1996). At the district level, planning for co-teaching includes discussion of district goals and objectives and how co-teaching may facilitate their achievement, issues of funding and resource allocation, and the public relational aspects of implementing co-teaching. At the building level, school administrators must consider staff selection for co-teaching, provision of common planning time for co-teachers, and scheduling of professional development in support of co-teaching.

Co-instruction. Effective co-teaching occurs when both teachers are actively teaching and working with students, and is not simply a teacher working with an assistant (Ploessl, Rock, Schoenfeld, & Blanks, 2010). Co-instruction is the fruition of the process of collaborative planning and provides a diagnostic regarding the health of a co-teaching relationship (Kohler-Evans, 2006). During co-instruction, co-teachers implement the lessons designed during co-planning (Conderman, 2011). With multiple teachers in a single classroom, co-taught lessons
should appear substantively different than what would be observed in a solo-taught class or in a classroom with a teacher and a paraprofessional (Murawski & Lochner, 2011).

Frequently discussed in the co-teaching literature are co-teaching models; co-teaching models describe the configuration of co-teachers during a co-taught lesson and their relationship to their students. Each model presents benefits and obstacles, and the choice of approach has implications for the efficacy of instruction and the perception of co-teaching and co-teachers by students and administrators (Keely, 2015). Clough, Berg, and Olson (2009) stress the importance of basing instructional decisions on learner characteristics; the co-teaching literature echoes this notion. Co-teaching models should be chosen based on knowledge of student and teacher characteristics, the content to be taught and what strategies facilitate learning that content, and the nature of the co-teaching situation (e.g., available space) (Cook, 2004). However, the literature cautions against an over-reliance on any one model and the neglect of student perceptions regarding co-teaching and its sundry manifestations. Co-teaching models represent the relationship between co-teachers and students and are not in themselves teaching practices; regardless of their choice of co-teaching model, co-teachers must not lose sight of the elements of effective instruction (Sileo & van Garderen, 2010).

Cook and Friend (1995) discuss five co-teaching models frequently used by co-teachers; these models are *one teach/one assist, station teaching, parallel teaching, alternative teaching,* and *team teaching.* The co-teaching literature contains numerous expansions and variations of these models (e.g., Thousand, Villa, & Nevin, 2006) as well as descriptions of more novel approaches to co-teaching (e.g., Kloo & Zigmond, 2008). The models described by Cook and Friend (1995) represent a developmental sequencing that reflects the amount of planning and
trust required for successful use of a given model; these authors emphasize that a valuative hierarchy among the models does not exist.

**One teach/one assist.** One teach/one assist occurs when one co-teacher takes a clear instructional lead while the other provides support, assists individual or groups of students, or simply observes. The one teach/one assist model is easy to implement and requires little advance planning (Cook & Friend, 1995) and may be useful in gathering information on student performance and behavior (Forbes & Billet, 2012) or in situations where observation of individual students is needed (Cook, 2004). Chang (2014) and Badiali and Titus (2010) note that this model may further be used as a vehicle for pre-service teacher learning during field experiences. Additionally, one teach/one assist may be helpful in co-teaching relationships in which one co-teacher possesses advanced subject knowledge while the other does not (Muraswki & Lochner, 2011). Due to ease of implementation, the one teach/one assist approach is the most frequently employed model of co-teaching (Harbort et al., 2007; Friend, 2007; Rice & Zigmond, 2000; Weiss & Lloyd, 2002). In a study of co-taught 41 classrooms representing 201 observations, Zigmond and Matta (2004), for example, noted only two instances in which the one teach/one assist model was not used.

Despite its popularity, however, the one teach/one assist model presents significant difficulties in terms of instructional efficacy and real and perceived co-teacher relationships. Counter to established rationales for co-teaching, with only a single teacher presenting substantive instruction, the one teach/one assist model presents the risk of an imbalanced use of teacher knowledge and experience (Weiss & Lloyd, 2002). Students may perceive one teach/one assist as representing an established hierarchy between co-teachers (Embury & Kroeger, 2012), with the assisting teacher viewed as subordinate to the lead teacher. Findings indicate that an
over-reliance on one teach/one assist may create this perception in teachers as well (Keefe & Moore, 2004). For instance, overuse of one teach/one assist may result in one teacher feeling relegated to the role of an aide (Murawski & Dieker, 2008). These issues are highlighted in Embury & Kroeger (2012), who reported that middle school students referred to their general education co-teacher as “the real teacher” (p. 109), while the job of their special education co-teacher was to work with students who “don’t learn as fast” (p. 109). In addition, Conderman (2011) notes that the one teach/one assist model may not provide adequate opportunities for balanced assessment.

Keely (2015) surveyed co-teachers and students in co-taught classes, noting that while teachers appreciated the ease of implementation present in one teach/one assist, the model significantly reduced opportunities for balanced instruction. Surveyed students expressed dissatisfaction with the approach, considering one teach/one assist to be “largely ineffective” (p. 12) at establishing balanced management routines and teacher authority and inferior to other co-teaching approaches in term of support for learning and student confidence. Based on student and teacher survey responses, Keely (2015) advised that one teach/one assist be used with discretion.

**Alternative teaching.** In alternative teaching, a small group of students is split from the class and works with a co-teacher, completing either an alternative lesson or the same lesson taught at a different level or for a different purpose (Cook, 2004, p. 20); the remainder of the class completes the lesson as planned. While a large amount of planning is required for alternative teaching, the approach may be useful when student apprehension of content varies widely or when co-teachers wish to present either remedial or enrichment material (Keely, 2105). While this model reduces the risk of perceived teacher hierarchy present in the one
teach/one assist approach, for students who receive remedial instruction in this way, there does remain the possibility of stigmatization (Cook & Friend, 1995).

**Parallel teaching.** Parallel teaching occurs when co-teachers plan a lesson and then divide the class, each teaching the same content to different groups of students in different locales. The reduced student-teacher ratio of student may encourage group discussions (Cook, 2004) and increased teacher interaction (Sileo, 2011). Similar to alternative teaching, parallel teaching may be used as a means of presenting either remediated or enriched content, as well as to make hands-on activities more engaging and manageable.

**Station teaching.** In station teaching, instructional content is divided, with co-teachers responsible for the planning and delivery of separate portions of the lesson. Teachers may work at fixed locations, with students rotating through each station; alternatively, student groups may remain stationary and co-teachers move to each group. Stations at which students work independently or in small groups may also be employed (Friend et al., 2010). Station teaching may be beneficial in situations in which students must complete a variety of tasks in support of a single learning objective (Dynak, Whitten, & Dynak, 1997). Although the lesson content at each station may be related, material presented at each station should be non-sequential (Sileo, 2011). In contrast to the one teach/one assist approach, teachers engaged in station teaching each play active roles in instructing students, thus mitigating the perception of hierarchy (Embury & Kroeger, 2012). Additionally, as students fully participate in each station, the risk of stigmatization by association with a special education teacher is reduced. Due to its reduced student-to-teacher ratio, station teaching may be particularly well-adapted for hand-on learning in science and mathematics (Forbes & Billet, 2012; Moorehead & Grillo, 2013).
Team teaching. Team teaching occurs when co-teachers simultaneously share the instruction of students (Cook & Friend, 1995); co-teachers may lead a joint discussion, for example, or participate together in a science demonstration. Team teaching is considered the most highly developed form of co-teaching (Reinhiller, 1996), and among the five co-teaching models, team teaching requires the most intensive planning and largest amount of trust and commitment (Cook & Friend, 1995). Findings by Chang (2014) support this notion. Longitudinal observations of 16 cooperating/student teacher co-teaching partners showed that the pairs more frequently engaged in team teaching as the semester progressed, representative of an increased level of comfort and trust between co-teacher which resulted in the use of more complex forms of co-teaching. Thousand, Villa, and Nevin (2006) note that team taught lessons should be structured so that each teacher has the opportunity to integrate their individual knowledge, skill, and experience.

Keely (2015) found that, among all forms of co-teaching, students least prefer the one teach/one assist model and find station and parallel teaching to be most supportive of learning and classroom management. While the five models described in Cook and Friend (1995) are frequently encountered, both in the literature and in practice, alternatives to these models have also been described. Supportive teaching for instance, occurs when one co-teacher designs activities that support instruction delivered by their co-teaching partner (Thousand, Villa, & Nevin, 1996). Interactive teaching (Walther-Thomas, Korinek, McLaughlin, & Williams, 2000) is a modification of team teaching; in this approach, teachers take on the role of lead instructor at fixed intervals.

Co-assessment. In addition to planning and teaching together, co-teachers are held jointly accountable for the academic performance of their students. While a great deal has been
written about the co-planning and co-instruction aspects of co-teaching, co-assessment has received comparatively little attention in the research literature (Conderman, 2011). During co-assessment, co-teachers gather student performance data from multiple sources, using this information to reflect upon the effectiveness of their teaching efforts and make instructional decisions (Conderman, 2011); similar to their peers in solo-taught classrooms, co-teachers have at their disposal a wide variety of formative and summative assessment strategies, including class discussions, entrance and exit tickets, written homework, and formal exams. In addition to academic assessment, co-teachers also collect information regarding student behaviors related to academic performance (Lingo, Barton-Arwood, & Jolivette, 2011). Co-assessment does not imply that co-teachers should work collaboratively to grade every piece of student work, but instead engage in discussions about what student data will be gathered and how to collect it, how it will be assessed, and how grades will be assigned (Murawski, 2009). Co-teachers bring with them to their co-teaching partnerships individual perspectives on assessment and grading; philosophical and practical differences regarding the nature and practice of assessment may result in conflict unless discussed in the early stages of a co-teaching relationship (Murawski & Dieker, 2008). To facilitate equal responsibility for the assessment of co-taught students, during conversations regarding co-teachers may use parity signals, such as referring to students as “our kids” as opposed to “my kids” (Murawski, 2009).

Factors That Facilitate Positive Co-teaching Outcomes

Co-teaching is a complex endeavor, representing the nexus of teachers, students, and the school; as such, a substantial number of factors, both internal and external to a co-teaching relationship, are required to make co-teaching successful (Mastropieri et al., 2005). Cross-contextual studies of co-teaching partnerships have identified a range of elements that support
positive co-teaching outcomes. Regarding these factors, several themes emerge from the co-teaching literature base: the importance of co-planning, professional and personal compatibility, appropriate delegation of responsibilities and roles, parity relationships, and administrative support.

**Co-planning.** As noted above, co-planning sessions present opportunities for co-teachers to share and discuss perspectives on instruction, assessment, and classroom management and also provide time for teachers to form personal and professional relationships. Not surprisingly, well-planned lessons are crucial in any classroom; effective planning is facilitated by the availability of time to plan and the efficient use of that time. Accordingly, findings from studies of co-teaching partnerships indicate that the amount of time available to engage in co-planning, and the efficient use of that time, is one of the most critical elements with respect to co-teaching. Kohler-Evans (2006) reports that common planning time was the most frequently mentioned feature of successful co-teaching relationships, while Friend et al. (2010) observed that co-teachers listed the ability to meet at least weekly to co-plan among items on a “dream list” of co-teaching responsibilities. Similar findings are noted in Bacharach, Heck, & Dahlberg (2008). Conversely, lack of adequate availability of co-planning time has been found to negatively affect co-teacher performance (Pratt, 2014).

While availability of co-planning time may be an element necessary for co-teaching success, it is not *a priori* sufficient: efficient use of time must be made during co-planning sessions. Dieker and Murawski (2003) report that an oft-heard complaint among co-teachers is an inefficient use of planning time, while Pratt et al. (2017) found that planning meetings may be sidetracked by distractions from colleagues, differences in planning strategies, and side conversations about students. Although teachers often stress the importance of co-planning,
Austin (2001) reports that while surveyed teachers in theory valued the ability to co-plan, those who actually met daily disagreed with the effectiveness of that practice. Further, participants in this study reported that negative experiences surrounding the provision of common planning time rendered the experience less effective.

**Professional compatibility.** The close and ongoing collaboration which co-teaching requires makes professional compatibility between teachers crucial. Co-teachers may come together with dissimilar professional values which they must combine to create positive academic and social climates for all students (Sileo, 2011, p. 34). Co-teaching partners unable to come to mutual understandings on individual philosophies of student learning and the role of the teacher are likely to experience difficulties in their shared classrooms (Cook & Friend, 1995). Not surprisingly, professional compatibility is frequently identified by co-teachers as being essential for their success (Kohler-Evans, 2006; Pratt, 2014; Rice & Zigmond, 2000). Required in successful co-teaching relationships are persons whose philosophies complement one another, with similarity of professional beliefs working to ensure that student learning goals are not inhibited (Pratt et al., 2017). Mastropieri et al. (2005), for instance, found that conflicting beliefs about planning, classroom management, and student interactions seriously inhibited positive co-teacher relationships. Rice & Zigmond (2000) write that teachers value shared views of academic and behavioral standards for students, and that without these things in place, students in observed classes became confused and frustrated in their co-taught classes. Further, teachers in this study placed a high priority on equal levels of content knowledge and instructional skill, feeling that professional compatibility was more of a concern than personal compatibility. In order to facilitate the process of making professional acquaintance prior to actually teaching together, Cook and Friend (1995) recommend that co-teachers discuss instructional beliefs,
planning and classroom routines, and “pet peeves” (e.g., acceptable level of classroom noise). Due to the personal nature of the information being shared, Conderman (2011) emphasizes the need for openness, professionalism, and honesty during these conversations.

**Personal compatibility.** Whereas professional compatibility relates to the degree to which co-teachers share similar theoretical and practical perceptions regarding aspects of education, personal compatibility describes co-teachers’ ability to work together harmoniously. Teachers surveyed by Scruggs, Mastropieri, and McDuffie (2007) considered personal compatibility the most essential ingredient for co-teaching success; personal compatibility was also rated highly by co-teachers studied by Rice & Zigmond (2000) and Keefe and Moore (2004). Similar findings have been reported in studies by Kohler-Evans (2006), Hang and Rabren (2009), and Walther-Thomas (1997). The degree to which co-teachers work together smoothly facilitates not only day-to-day teaching, but also serves as an indicator of the viability of a continuing co-teaching partnership. Numerous articles discussing the logistics and requirements of effective co-teaching have appeared in the practitioner literature, with many recommending that co-teachers make a concerted effort early in the partnership to get to know each other (e.g., Gately & Gately, 2001; Sileo, 2011).

**Roles and responsibilities.** Teaching is a complex undertaking, requiring a high degree of effort, planning, and logistical efficiency; in co-teaching, although work may be distributed between two people, additional complexities created by the introduction into the classroom of a second teacher require an equitable and pre-meditated allocation of effort and responsibility. Accordingly, the delegation of responsibilities and the roles teachers play in their relationships with co-teaching partners are identified as an essential element of positive experiences with co-teaching (Dieker, 2001; Fennick & Liddy, 2001; Kohler-Evans, 2006). Poorly defined roles may
result in idiosyncratically developed partnerships that may invite confusion and create conflict between co-teachers (Bledsoe, Shieh, Park, & Gummer, 2004).

In co-teaching partnerships, co-teacher roles may include instructor to a whole class, disciplinarian to a whole class or a group of individual students, or classroom manager (Bouck, 2007). Co-teaching relationships in which roles and responsibilities are not clarified run the risk of negative impacts on student performance (Rice & Zigmond, 2000). In addition, ill-defined assignment of roles and responsibilities may lead to a co-teaching partnership that is dominated by one teacher, attendant loss of professional self-efficacy and student respect on the part of the less-powerful teacher (Hang & Rabren, 2009). This risk is particularly prevalent in partnerships between general and special educators, and in situations where one co-teacher is a content specialist while the other is not (Austin, 2001; Friend & Cook, 2000). Similar to the gauging and establishing of professional and personal compatibility, findings from co-teaching research indicate that discussions regarding distribution of effort, duties, and accountability are most effective when started early in a co-teaching relationship and occur on an ongoing basis (Kohler-Evans, 2006; Sileo, 2011).

**Parity.** Parity indicates equality of status. In co-teaching, parity between teachers means that teachers share planning, instructional, assessment, and management duties equitably and consider themselves professional equals, with students also recognizing this equality (Sileo, 2011). Numerous studies have found that balanced relationships between co-teachers are a critical element of successful co-teaching experiences (Pratt, 2014; Pratt et al., 2017; Rice & Zigmond, 2000). Teachers that are equal partners show few professional distinctions between them (Sileo, 2011), with students interacting with teachers equally. Teacher questions, instructions, and management decisions are given equal weight, with neither teacher being
viewed as the “real teacher”. Hang and Rabren (2009) indicate that frequent communication and well-defined roles and responsibilities are critical in establishing parity between co-teachers. Further, as previously described, parity between co-teachers may be promoted or inhibited by certain co-teaching models. Overuse or misuse of the one teach/one assist model, for instance, can result in students viewing a more passive teacher as an aide or volunteer (Cook & Friend, 1995); models in which students have equal access to both teachers, such as station or parallel teaching, are much less likely to obscure the relational equality between co-teachers (Keely, 2015).

**Administrative support.** Nearly every study of teacher performance has noted that the support of school administrators is essential for teacher success (Friend et al., 2010). Administrative support has been found to play a similar role in co-teaching (Mastropieri et al., 2005; Pratt, 2014). Many educators asked to begin a co-teaching partnership do so with little advance knowledge of the logistics and requirements involved, and it is the duty of district and school administrators to provide training opportunities related to co-teaching. Keefe & Moore (2004) report that many special and general educators do not feel prepared for the demands placed upon them with regard to collaboration skills and content knowledge; teachers in Keefe and Moore’s study felt that this gap in teacher knowledge may have been addressed through ongoing professional development. Further, many teachers are constrained in their ability to work together to plan for co-teaching by the building schedule; as noted above, the inability to procure common planning time has been a perennial complaint among co-teachers. Given the importance of co-planning, school officials should be proactive in making available common planning time for co-teachers (Pratt, 2014). In order to make the most of collaborative teaching, Trent et al. (2003) emphasized the need for increased communication between teachers, building
administrators, and district support personnel. Keefe & Moore (2004) note that administrative support for co-teachers should include a commitment to provide adequate planning time, limited class sizes, and opportunities for professional growth.

**Applications of Co-teaching**

Historically, co-teaching is rooted in school reform efforts implemented in the late 1950s (Friend & Reising, 2003), coming into its own as a practice and object of research following an increased emphasis on inclusive education. While co-teaching in contemporary schooling mainly occurs in special education settings and general education content area teaching, it has also found a home in pre-service teacher education and as vehicle for the inclusion of STEM professionals in primary and secondary science education.

**Pre-service teacher education.** Student teaching is the culminating experience for many pre-service teachers. Typically occurring during the final semester of a teacher education program, in student teaching, pre-service teachers work with a cooperating teacher to put into practice the knowledge and skills learned in university coursework. Although student teaching is often viewed by teachers as one of the most powerful experiences of their teacher education programs, in many cases, conditions in the host school or university are such that the impact of the experience is limited. Field experiences may be disconnected from university coursework and organized haphazardly, and state boards of education may provide minimal guidance as to the extent and content of student teaching (Heck & Bacharach, 2016). Further, many cooperating teachers expect their student teachers to enter the experience already skilled in instruction, planning, and classroom management (Bacharach, Heck, & Dahlberg, 2010); to be successful, student teachers simply need to apply this knowledge in an “unproblematic way” (Roth, 1998). However, many student teachers encounter difficulty bridging the gap between
university coursework and real-world classroom experiences. In addition, while cooperating teachers are to a large extent responsible for the mentoring and development of student teachers, teacher education programs often provide little guidance to cooperating teachers as to how these responsibilities are to be performed (Giebelhaus & Bowman, 2000). Thus, cooperating teachers may vary widely in their ability to mentor and support student teachers. Further, the student-cooperating teacher relationship may be complicated by perceived imbalances in social power related to the cooperating teacher’s role in student teacher evaluation (Anderson, 2007). Despite these difficulties, however, the student teaching experience has remained a critical part of the process of teacher education (Ronfeldt & Reininger, 2012).

Cooperating teachers share a classroom and instructional responsibilities with their student teachers; this arrangement is similar to a co-teaching partnership. Cooperating and student teachers engaging in collaborative planning, instruction, and assessment as social equals may limit the imbalance of power between them (Bacharach, Heck, and Dahlberg, 2010). From this perspective, co-teaching in similar in nature to an apprenticeship, with prospective teachers “learning to teach at the elbow of another” (Roth & Tobin, 2005). Taking an apprenticeship view of student teaching, learning to teach is considered a socially constructed and collaborative undertaking in which both mentor and student teachers learn from each other (DelColle & Keenan, 2015). Roth (1998) observes that when novice teachers participate in practice with an experienced mentor, they see important principles in practical action (p. 372) and acquire knowledge more rapidly than had they learned it on their own.

Bacharach, Heck, and Dahlberg (2010) outline several significant differences in planning and instruction that exist between the traditional and apprenticeship approaches to student teaching. Student teachers in the traditional model are frequently expected to arrive at student
teaching already skilled in both planning and teaching. From the perspective of an apprentice field experience, however, the more experienced mentor teachers provide ongoing modeling and makes explicit the rationales for specific instructional decisions (Bacharach, Heck, and Dahlberg, 2010, p. 11). Such an approach is visible in the process of planning lessons; rather than leaving student teachers to plan lessons on their own and submit them for approval before implementation, co-teachers engage in a model of cooperative planning in which the responsibility of planning lessons is gradually transferred from mentor to student teacher.

Regarding instruction, in the traditional approach, student teachers may spend up to several weeks observing before being handed lead teacher duties. In contrast, in the apprenticeship placement student teachers are involved with some level of instructional duties from the first day (DelColle & Keenan 2015). Cooperating teachers work with the student teacher to develop facility in delivering instruction from the beginning of the experience, gradually handing over the lead teacher role while still remaining a participant in the activity of the classroom (DelColle & Keenan, 2015, p. 8). In this way, novice teachers may learn the essential elements of teaching even in cases when they are not made explicit (Roth, 1998, p. 372).

The apprenticeship approach to student teaching offers advantages to both students and teachers. In addition to experience gained through close collaboration with a more experienced other, the *a priori* establishment of parity between the student and cooperating teachers helps students more easily understand that the prospective teacher is a “real” teacher (Bacharach, Heck, & Dahlberg, 2008; Chang, 2014). Further, professional growth in apprenticeship field placements is not the sole possession of student teachers. Roth and Tobin (2005) note that teacher growth through apprenticeship placements is a symmetric process in which both cooperating and student teachers learn from each other; given their recent experience in a teacher
education program, student teachers may share with their cooperating teachers new content knowledge and fresh perspectives on teaching. Through the practice of teaching together, student and mentor teachers may also create collective understandings of their collaborative practice, enriching their knowledge of what it means to teach (Scantlebury, Gallo-Fox, & Wassel, 2008). More concrete benefits have also been observed. Students in apprenticeship student teaching placements made significant gains in reading and math when compared to students in solo-taught classes (Bacharach, Heck, & Dahlberg, 2008). As well, participants in apprenticeship placements studied by DelColle & Keenan (2015) reported more efficient use of time, better connections with students, and reduced administrative duties pursuant to the combine efforts of two teachers.

**GK-12 program.** The late 1990s saw the roll-out of the NSF-funded Graduate STEM Fellows in K-12 Education (GK-12) program. GK-12 provided funding for universities to place graduate students in engineering, science, or mathematics with K-12 classroom teachers to promote enhanced student STEM experiences while simultaneously presenting participants with opportunities for mutual professional growth. Before the close of the program in 2000, GK-12 projects were implemented by over 100 universities in the United States and Puerto Rico (Brewer et al., 2013).

GK-12 fellows worked collaboratively with K-12 classroom teachers to co-plan and co-teach science, engineering, and mathematics lessons. While a boilerplate GK-12 experience did not exist, the majority of GK-12 teaching fellows engaged in some form of co-teaching with their teaching partner (Brewer et al., 2013). A crucial goal of GK-12 was the promotion of mutual professional development (Gamse et al., 2010). In keeping with Roth and Tobin’s (2005) notion of co-teaching as a vehicle for symmetric professional growth, through interaction with STEM
experts, classroom teachers would learn new content knowledge and become familiar with scientific laboratory and field work. By working with their assigned teacher partner, graduate student fellows would gain improved teaching skills and improve their communication of STEM content to non-scientist audiences.

The GK-12 approach is rooted in the theory of distributed expertise (McNeal et al., 2013). Professionals have a well-defined set of knowledge and skills that are accessed for work in a specific area; while professional skillsets may overlap, professions are to a large extent defined by the particular knowledge domains native to each. A system of distributed expertise exists when two or more professionals combine individual skillsets and engage them in work on a single task or set of related tasks; the knowledge required to complete the task does not rest with any one individual, but rather in the combined intellect created by the admixture of professional knowledge and skill. In GK-12, classroom teachers and STEM graduate students combined knowledge of their respective fields to collaboratively plan and implement science, engineering, and mathematics lessons. K-12 classroom teachers are prepared in developmentally appropriate approaches to pedagogy, lesson planning, and classroom management, while STEM graduate students are experts in a science, engineering, or mathematics discipline; the amalgamation of knowledge and skill possessed by members of GK-12 partnerships created a knowledge base greater than that possessed by either individual.

GK-12 fellow-teacher partnerships were similar to more general co-teaching relationships. Many of the factors that support positive co-teaching outcomes also appear in research literature related to GK-12 programs; these include the need for open communication, administrative support, and positive interpersonal relationships. However, the experience and expertise differential between the classroom teachers and graduate teaching fellows created
challenges not seen in traditional co-teaching arrangements. McNeal et al. (2013), for instance, stated that perceived differences in status between science content knowledge and teacher pedagogical knowledge may have created the conditions for a hierarchy to exist between GK-12 teacher-fellow partners. In addition, as both participants in a GK-12 experience were relative experts in their fields, either may have been able to influence their partnerships through the wielding of expert power (French & Raven, 1959).

Findings from studies of GK-12 programs indicate that collaboration between a classroom teacher and a STEM discipline expert may be beneficial to both teachers and students. Pursuant to their work with their assigned teaching fellows, classroom teachers experienced increased science and engineering content knowledge (Caicedo, Lyons, & Thompson, 2006), increased engineering and science teaching self-efficacy (Gamse et al, 2010), an increased fluency with inquiry teaching (Trautman & Makinster, 2005), and increased confidence and skill in teaching engineering (Orr, Quinn, & Rulfs, 2007). Researchers found evidence of increased pedagogical knowledge and skill among the graduate teaching fellows as well. Thompson, Watson, & Lyons (2010) observed an increase in science teaching self-efficacy among GK-12 teaching fellows, while an increased awareness of the complexities of teaching and learning were noted by Gravel et al. (2005). Fisher & Lyons (2004) and Orr, Quinn, & Rulfs (2007) noted improvement in the teaching fellows’ ability to engage students in STEM activities, as well as improved classroom management during activities. In accordance with potential program goals, Fisher & Lyons (2004) observed an increased awareness and use of developmentally appropriate instructional strategies. Improvements in communication skills with K-12 students were reported by Mitchell et al. (2003), while Gravel et al. (2005) described an increased fluency in discussing science concepts with non-scientific audiences. Students also benefited from GK-12
programs. Gamse et al. (2010) reported increased knowledge of science and mathematics content, while Lyons (2011) observed that students displayed increased accuracy with respect to conceptions of engineers and engineering related to their experiences with a GK-12 teacher-fellow partnership.

While findings from research on GK-12 programs indicate that collaboration between K-12 classroom teachers and STEM graduate students may benefit teachers and students, an important caveat is warranted. Many of the results presented above were based on analysis of self-reported survey data, creating the potential for response biases; classroom observations of the teachers and graduate teaching fellows who provided self-reports may have increased the scope and reliability of findings. While the findings presented above speak to the potential efficacy of the GK-12 approach, further research is required to more fully understand the impact of programs of this nature.

**Teams and Team Effectiveness**

Co-teachers work closely on tasks that require positive interpersonal relationships, close coordination, and a sharing of mutual expertise. Relative to co-teaching dyads, the presence of the third member in a co-teaching triad may complicate the distribution of group effort and instructional responsibility and may increase the potential that interpersonal dynamics will influence group functionality. Three-person groups represent the smallest collective in which group dynamics operate (Menon & Philips, 2011). Perspectives and findings from the areas of organizational psychology and behavior may thus help to more fully understand the functioning of STEM co-teaching triads in the context of the classroom. The following sections explore foundational concepts of teamwork theory.
Work Groups and Work Teams

A group is a collection of two or more individuals connected through social relationships (Forsyth, 2014) that exists for a reason and whose members feel a sense of shared purpose (Levi, 2007). Groups that exist in the context of an organization and engage in job-related tasks are called work groups. Work groups vary widely in structure, composition, function, and organizational context and exist across continuums of member autonomy and interdependence. A subset of work groups are work teams. Work teams differ from work groups in terms of their internal characteristics and functionality (Kinlaw, 1991). Within the literature, disagreement exists regarding the efficacy of considering work groups and work teams to be substantively different phenomena (Kozlowski & Bell, 2003). Co-teaching triads are unique entities, however, and thus careful consideration of subtle distinctions is warranted.

Traditional work groups perform production functions and do not engage in any other sort of task (Banker, Field, Schroeder, & Sinha, 1996). Traditional work groups often perform additive tasks; additive tasks are those in which the performance output of a group is the sum of the output of each member (Forsyth, 2014). In traditional work groups, little coordination between group members is required, and the performance of one member is not dependent on the performance of another (Johnson & Johnson, 2003). In groups that perform complex tasks, members often perform specialized functions; in these cases, increased group member coordination may be required. In turn, the emergent need for specialization and increased coordination may result in the generation of a system of group member interdependencies.

Work groups differ from work terms in terms of member interdependence and autonomy (Banker et al., 1996; Katzenbach & Smith, 1993). Member interdependence refers to the extent to which group members interact and depend on each other for group functionality (Guzzo &
Shea, 1992); in work teams, member interdependence is higher than in work groups (Forsyth, 2014). Member autonomy relates to the ability of group members to regulate the management and execution of tasks; member autonomy is also higher in work teams than in work groups (Banker et al., 1996). In addition, work groups and work teams differ with respect to locus of accountability. Members of work group are often rewarded as individuals and are held accountable for the individual work they complete (Johnson & Johnson, 2003). In contrast, members of work teams are held accountable for both their individual work and the performance of the team as a whole (Forsyth, 2014; Johnson & Johnson, 2003). Relative to work groups, work teams perform tasks that are complex and multifaceted. As such, team members often represent different areas of expertise, and team roles are assigned based on possession of specialized individual expertise. The distributed nature of team task work and expertise allows teams to function more smoothly in complex and dangerous environments than other types of groups. Thus, teams often operate in stressful environments exemplified by (1) rapidly evolving and ambiguous situations; (2) no optimal or “correct” answer; (3) time pressures; (5) severe consequences in case of error (Salas, Stagl, Burke, & Goodwin, 2007).

Within the research literature, a canonical definition of team has not yet been settled upon. Most definitions, however, share a general set of characteristics. A work team is a collection of individuals embedded in an organization working toward a collective goal whose members share a high degree of mutual interdependence and are able to regulate the manner in which individual and group tasks are performed. Operating in often ambiguous or stressful environments, members of work teams are bound by stable social interactions (Kinlaw, 1991) and a shared sense of accountability for the performance of the group. The knowledge and skill required to complete work-related tasks is often distributed among team members, and members
of the team are assigned roles and functions based on their individual areas of specialization. Teams thus represent more than a collection of people working together. Teams are complex, interdependent entities that combine individual effort and resources and focus them on the attainment of a shared goal.

**Types of teams.** Teams perform some of the most critical functions in the global economy, including emergency response, air travel, and national defense (Salas et al., 2007). Given the variety of tasks performed by teams, the composition and structure of teams varies widely. Understanding the nature of a particular type of team is essential in optimization and assessment of task performance and enables researchers to frame pertinent questions and establish generalizability of results (Cannon-Bowers & Bowers, 2011, p. 600). Many taxonomies of teams are described in the research literature. An frequently cited synthesis by Sundstrom, McIntyre, Halfhill, and Richards (2000) identifies *production teams, service teams, management teams, project teams, action and performing teams, and advisory teams*. Cohen & Bailey (1997) discuss *work/parallel teams, project teams, and management teams*. More recently, West (2012) defines five broad categories of teams: *strategy and policy teams, production teams, service teams, project/development teams, and action/performing teams*. In addition to differences in team functionality, comparisons between team type have been made based on (1) the level of authority given the team within its parent organization; (2) the length of time the team is operative; (3) the degree of specialization, independence, and autonomy in relation to other work units; (4) the extent to which team members work interdependently (Salas, Burke, & Cannon-Bowers, 2000).

**Types of tasks.** The nature of the task a team performs has important implications for the functioning of the team and acts as a theoretical lens through which to view team processes.
and performance. The composition and structure of the team, availability of resources, and the methods used to assess team performance are all in part dictated by the nature of the team task. Team member roles and functions are often assigned based on task type, and teams whose members possess skills ill-suited to the task, or do not have access to adequate resources, may be less likely to function effectively than those that do. Team tasks further dictate the primary focus of team members and influence the structure of team workflow and coordination (Kozlowski & Ilgen, 2006). Teams may perform a variety of tasks or they may focus solely on one type of task (Forsyth, 2014); however, effective performance on one type of task does not a priori generalize to other tasks (Levi, 2007). Teams may also perform tasks whose characteristics overlap (McGrath, 1984). Further, the type of task performed by a team is often a crucial factor in characterizing the nature of effective teams and assists in providing the criteria against which team effectiveness is measured (Hyatt & Ruddy, 1997).

Steiner (1972) proposed an influential taxonomy of team tasks whose independent variable is the manner in which team member labor is combined. Tasks that are divisible into smaller subtasks that can be distributed among team members are known as divisible tasks; tasks for which subdivision is not possible are unitary tasks. Additive tasks are divisible tasks that require each team member to play an equal role. In this case, team output is defined as the sum of the work completed by each member and will thus always exceed the output of any single member; the unloading of a truck by a group of workers is an example of an additive task. A conjunctive task is a divisible task on which all members must work at some minimally acceptable level (Cannon-Bowers & Bowers, 2011), with team output being limited by the worst-performing team member; assembly line work is an exemplar of a conjunctive task. Conversely, tasks whose successful performance requires the effort of only a single team
member are known as *disjunctive tasks* (Barrick, Stewart, Neubert, & Mount, 1998); the highest level of performance available to a team performing a disjunctive task may be that of its most highly performing member. Disjunctive tasks often require the selection of a single solution or right answer. *Compensatory tasks* are those in which team member effort is combined in such a way that team output is a function of the average effort and ability of each member; a team of weather forecasters working together to create a single forecast are performing a compensatory task. Teams may also combine effort, experience, and resources in a manner of their choosing; teams collaborating in such a way are said to be working on *discretionary tasks* (Forsyth, 2014).

Understanding the nature of a team task provides a theoretical lens through which to interpret team processes and effectiveness. For instance, a particular team may perform better on one type of task than another; accurate assessment of team effectiveness would not be possible without some knowledge of the team task. An understanding of task typology may also play a role in decisions regarding team staffing and allocation of resources (Kozlowski & Bell, 2003).

**Team Effectiveness**

Teamwork is ubiquitous in contemporary work environments, and an understanding of the factors that amplify or inhibit a team’s ability to perform its tasks is essential to building, managing, and maintaining quality teams. Teams perform tasks, and the level of *team performance*, defined by Hackman (1987) as the extent to which the product or outcome of team actions satisfy an external constituency, achieved by the team is critical. However, team members have a variety of social and emotional needs which their fellow team members, leaders, or organizational context may satisfy or frustrate. Members of teams which meet these needs are more likely to feel valued and respected within the context of both the team and organization, paving the way for further teamwork (West, 2012). On the other hand, members of teams that
incite dissatisfaction or dissent among members may be less likely to work together effectively and may eventually descend into open conflict. While the notion that team member relationships always interact synergistically to enhance team performance is intuitively appealing, the connections between team performance and team member relationships are not always straightforward (e.g., Kong, Konczak, & Bottom, 2015; Li, Li, & Wang, 2009).

This dual nature of team success is captured in the construct of *team effectiveness*. As it is the function of teams to perform tasks, the level of team performance achieved by a team is critical; however, in order to function smoothly and maintain viability, team members must also be able to work together in a way that satisfies their employment-related needs. Team effectiveness is therefore a value judgement into which both externally assessed performance outcomes and perceptions of team member harmony and satisfaction factor. Effective teams thus do more than perform at a high level; in addition to strong task performance, effective teams promote positive interpersonal relationships and individual satisfaction among team members.

Team effectiveness as a construct has been difficult to operationalize (Salas et al., 2007) and numerous characterizations of effective teams exist in the literature. Hackman (1987) defines team effectiveness as the extent to which teams (1) complete assigned tasks in a satisfactory manner; (2) maintain intra-team relationships supportive of future collaboration; (3) meet the social and cognitive needs of team members. Campion, Medsker, and Higgs (1993) operationalize team effectiveness in terms of team member satisfaction, measurements of team productivity, and managerial assessment. Further, Sheard and Kakabadse (1997) frame team effectiveness as a function of four “basic elements” (p. 138): task, individual, group, and environment. Additional theories of team effectiveness account for temporal processes of team development and maturation (Kozlowski & Bell, 2003; Salas et al., 2007).
Team effectiveness models. While definitions of team effectiveness describe the things effective teams do, team effectiveness models seek to explain how effective teams work. Team effectiveness models map the associations between team member characteristics, the team’s organizational context, and its performance outputs (Hackman, 1987). While the research literature contains a diverse array of both theoretical and empirical models of team effectiveness, most trace their conceptual heritage to a single ancestor: McGrath’s (1964) input-process-output (IPO) model (Cannon-Bowers & Bowers, 2011; Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Kozlowski & Ilgen, 2006; Salas et al., 2007; Stewart & Barrick, 2000). In this context, input refers to the multiplicity of individual, group, and organizational level factors influencing team effectiveness (Kozlowski & Bell, 2003); inputs may include team member knowledge, skill, and personality attributes, organizational reward structures, and the nature of the team task. Processes are the interactions and coordinated efforts among team members required for performing team tasks and achieving team goals (Baker, Horvath, Campion, Offerman, & Salas, 2005); team processes may include communication, cooperativity, and resolution of conflict. Outputs are the criteria used to assess the team’s actions (Kozlowski & Bell, 2003); team outputs may include completed work tasks and their associated quality, managerial assessments, and member behavioral and attitudinal outcomes. In the IPO model, internal and external factors (inputs) interact with team processes, which in turn influence the extent to which a team successfully accomplishes its mission.

An influential IPO-type model is Hackman’s normative model (1987). Expanding the standard IPO framework, the normative model emphasizes organizational contexts and specific team member skills and strategies (Cannon-Bowers & Bowers, 2011). From this perspective, team effectiveness is measured along three axes: (1) performance assessment; (2) team viability;
(3) team member satisfaction. Campion et al. (1993) describe an empirically supported team effectiveness model created in coordination with a meta-analysis of team effectiveness studies and observation of work teams. This model correlates five factors with effective team performance, as measured by productivity, team member satisfaction, and managerial assessments: *job design, member interdependence, team composition, organizational context,* and *team processes.*

IPO relationships have been extensively studied and provide a useful heuristic for discussing the general notion of team effectiveness. However, an emergent consensus within the literature holds that IPO models leave unaddressed several crucial aspects of team effectiveness. From these perspectives, IPO models do not adequately account for the maturational nature of team effectiveness and fail to address synergistic interactions between input variables and team processes (Kozlowski & Bell, 2001; Mathieu, Maynard, Rapp & Gilson, 2008). Models addressing these concerns have been developed. Ilgen et al. (2005), for instance, discuss *input-mediation-output-input* (IMOI) models, a modification of the IPO framework that describes team effectiveness in terms of *mediation* between input variables and effectiveness criteria, rather than a linear process between input and output, and that accounts for feedback processes arising from the interaction between input variables and team task performance.

**Factors that impact team effectiveness.** Much work has been done with regard to the identification of factors that promote and support effective teams; the objective of this work has been the development of a set of recommendations for the design and staffing of effective work teams (Campion et al., 1996). Little consensus exists regarding a canonical list of the factors affecting team effectiveness (Campion et al., 1996; Sundstrom et al., 2000; Cohen & Bailey, 1997; Cannon-Bowers & Bowers, 2011), and numerous theoretical perspectives have been
advanced. In IPO models, such factors are considered proximal predictors of team effectiveness (Kozlowski & Bell, 2003) and may function as both inputs and processes; each factor possesses a continuum of effects and may serve to amplify or inhibit team effectiveness. Given the numerous theoretical perspectives present in the literature, a thorough exploration of the factors that influence team effectiveness would be prohibitive. A useful schematic for investigating the factors that influence team effectiveness is presented by Sundstrom et al. (2000). From this perspective, the factors that influence team effectiveness are categorized as organizational factors, team composition factors, work design factors, intragroup factors, and external factors; this collection of factors has been empirically associated with team effectiveness (Sundstrom et al., 2000). However, definitively associating a specific factor with a particular team-level outcome has been challenging, and many open research questions exist in addition, many studies report results that relate only to a specific type of team, task, or setting. Thus, a priori generalizations related to the connections between a team’s composition, organizational context, and task type may be problematic.

**Organizational factors.** The organizational context in which a team works may directly or indirectly influence team effectiveness. Organizational factors that impact team effectiveness include remuneration and reward structures, institutional infrastructure, leadership and supervision, and opportunities for team training (Cohen & Bailey, 1997; Hackman, 1987; Sheard & Kakabadse, 2000; Sundstrom et al., 2000). Organizational reward structures, for example, have been observed to enhance team effectiveness in interesting ways (e.g., Cohen et al., 1996). Teams whose work requires lower degrees of member interdependence have been observed to perform better when rewards are offered at the individual level, whereas teams whose tasks require a higher degree of interdependence perform best when performance is rewarded at the
team level (Wageman, 1995). Further, team effectiveness is most efficaciously promoted through opportunities for team training when teams engage in self-monitoring and self-corrective training and training that supports increased degrees of team interdependence and coordination (Marks et al., 2000; Salas et al., 2007). Team training programs involving cross training (in which team members train on various team roles) and scenario-based training (training on realistic scenarios) have produced mixed results with regard to improved team effectiveness (Cannon-Bowers & Bowers, 2011). Organizations may also support effective teamwork by providing adequate resources, presenting teams with a clear purpose for their work, and recognizing and valuing teamwork (Mickan & Rodger, 2000).

**Team composition factors.** Team composition factors relate to the structural and demographic characteristics of teams; included among team composition factors are demographic diversity, distribution of team member ability and personality, and team size. Team composition factors are related to team effectiveness through the direct effect they have on the amount of knowledge, skill, and experience individuals bring to their teams (Bell, 2007). Team members must work together, and not all team members will get along; team effectiveness depends, in part, on how the demographic and personality characteristics of team members interact (Mohammed & Angell, 2003). A great deal of effort has gone into understanding the optimization of team structure and demographics; following is a survey of key findings related to team composition variables.

**Aggregated team characteristics.** Teams are composed of individuals with particular sets of skills and characteristics. In many instances, research on teams requires that individual personality variables be combined into an aggregate quantity that is understood to represent the team-level amount of that characteristic. Individual characteristics are often measured through
the administration of quantitative survey instruments, providing convenient means to create an aggregated, team-level response (Gosling, Rentfrow, & Swann, 2003). Common methods of aggregating individual characteristics into a team-level quantity include averaging individual amounts of a characteristic, using the individual minimum or maximum scores, and examining the variability between individual scores. Steiner’s (1972) taxonomy of team tasks is often turned to for guidance regarding which method of aggregation is appropriate for a given situation (Barrick et al, 1998; Cannon-Bowers & Bowers, 2011; Devine & Philips, 2001). For teams performing additive tasks, the mean individual responses may be appropriate; averaging member scores reflects the assumption that an individual’s characteristics impact team effectiveness linearly (i.e., that more of a certain trait will always be better for the team) (Barrick et al., 1998). Operationalizing a team-level variable as the maximum individual score may be appropriate for disjunctive tasks, in which team success can be achieved through the efforts of only a single individual. Conjunctive tasks are those that may be significantly impacted by the least high performing individual; for these types of tasks, operationalizing the team rating as the minimum individual score may be appropriate. Representing a team-level score with the maximum or minimum individual score promotes the notion that a single individual may significantly impact team functionality (Barrick et al., 1998). Interpreting a team-level quantity as the variability between member scores is suitable for compensatory tasks, which require a combination of individual efforts. Representing a team characteristic as the variability between individual scores is reflective of the notion that team-level properties are a function of the level of diversity among individuals (Neuman et al., 1999).

Size. Conceptually, the number of individuals working together on a team should have a noticeable impact on team effectiveness. (Cannon-Bowers & Bowers, 2011). Teams that are too
large for their assigned work will experience redundancies in member roles, possibly leading to internal confusion and conflict, while teams that have too few members may struggle with overwhelming workloads. Early research into the impact of team size on team effectiveness found that an increased number of team members effected an overall decrease in member satisfaction. Additionally, the number of potential relationships between team members increases quadratically with team size; the increased number of member relationships in larger teams may lead to untenable demands for team coordination (Hare, 1981). More recent studies of the relationship between team size and team effectiveness (e.g., Stewart, 2006; Mohammed, Cannon-Bowers, & Foo, 2010) has produced mixed results, and the identification of an optimum team size for a given task has thus far proven elusive (Cannon-Bowers & Bowers, 2011).

Kozlowski and Bell (2003) note that these difficulties are likely related to methodological difficulties and the multifaceted nature of team effectiveness and do not indicate the presence or absence of an effect.

While the impact of team size on team effectiveness may be unclear, worth noting is a concern raised by Hare (1981): teams with more than two members display differences based on the parity of team size which may cause them to split into subgroups. Important examples of this effect are found in Simmel’s (1950) and Caplow’s (1968) extensive work with triadic groups. Simmel hypothesized that groups composed of three members will, with near certainty, exhibit a tendency to splinter into “two against one” subgroup coalitions. Expanding on this work, Caplow (1968) observed eight distinct subgroups formed through this process and hypothesized that perceived differences in social power between team members served as the catalyst for coalition-building. Work by Menon and Philips (2011) supports this conclusion; small groups were observed to experience greater group cohesion when team size was of even parity.
Demographic diversity. Team demographic diversity refers to the extent that teams are heterogeneous with respect to demographic variables such as age, gender, and ethnic identity. The influence of team demographic diversity on team effectiveness has been difficult to determine. Pelled, Eisenhardt, and Xin (1999) observed that while demographic variables may impact team effectiveness, different types of diversity have differing effects. Kozlowski & Bell (2003) noted that studies have found demographic diversity to have positive, negative, and no influence on team effectiveness. Mannix and Neale (2005) and Horwitz and Horwitz (2007) also reported mixed results with respect to the influence of team diversity on team effectiveness. Cannon-Bowers and Bowers (2011), however, state that such mixed results do not diminish the importance of team demographic diversity, but rather highlight the complex nature of the involved relationships.

Member personality. Teams are composed of individuals, and the distribution of personality characteristics within teams, and the interactions between personality and teamwork functions, have been the subject of a great deal of research effort. Findings from this area of research indicate that team member personalities may noticeably impact team effectiveness (Kramer, Bhave, & Johnson, 2014; Mount, Barrick, & Stewart, 1998; Neuman, Wagner, & Christiansen, 1999; Neuman & Wright, 1999; Stewart, 2006). However, the relationships between member personality and team effectiveness are complex and often mediated by task variables (Kozlowski & Bell, 2003; Peeters et al., 2006).

Research on personality in the workplace, at both the individual and team levels, has made frequent use of the “Big Five” model of personality. Emerging out of decades of empirical and theoretical work on the structure of personality, the Big Five model is a taxonomy of personality attributes that has been validated in a variety of contexts and across instruments.
(Barrick & Mount, 1991; Digman, 1990; McCrae & Costa, 1987). Due to the proliferation of models of personality, prior to the recognition of the Big Five as a convincing model of personality, little headway was made in understanding the relationships between team member personality and team effectiveness, largely (Neuman, Wagner, & Christiansen, 1999).

The personality characteristics described in the Big Five model are *extraversion*, *agreeableness*, *openness to experience*, *conscientiousness*, and *emotional stability* (in some studies referred to as *neuroticism*). *Extraversion* refers to the extent to which individuals are outgoing, assertive, social, and talkative, as opposed to quiet, reserved, and cautious (Neuman et al., 1999). *Agreeableness* describes the extent to which individuals are kind, trustworthy, and warm versus selfish, distrustful, and hostile (Driskell et al., 2006). *Openness to experience* (found in some studies as *openness*) represents the degree to which individuals possesses personality characteristics related to open-mindedness, curiosity, and intelligence (Barrick & Mount, 1991). Persons displaying high levels of *conscientiousness* are organized, hardworking, reliable, and trustworthy, while those low in this characteristic may be impulsive, irresponsible, and disordered (Driskell et al., 2006); several studies have found that conscientiousness within teams may be predictive of team effectiveness (Kozlowski & Bell, 2003). *Emotional stability* characterizes the extent to which individuals are relaxed, even-tempered, and able to handle stressful situations without becoming upset; those low on this scale may be easy to anger and have difficulties coping with stress (Rothmann & Coetze, 2003).

Numerous studies have empirically supported the notion that team member personality affects the ability of teams to function effectively. Early work by Tuckman (1964) showed that the behavior of a group may be predictable using knowledge related to the personality distribution of its members. Work by Barrick et al. (1998) correlated high team-level means on
the Big Five personality domains of conscientiousness, agreeableness, extraversion, and emotional stability with positive appraisals of team performance by supervisors; the same study showed that team viability was enhanced when teams had high mean scores in the extraversion and emotional stability domains. Neuman et al. (1999) found similar results, showing that team mean scores on the conscientiousness, agreeableness, and openness to experience domains positively correlated with team task performance. Neuman and Wright (1999) found agreeableness and conscientiousness to be predictive of team effectiveness. More recently, studies by Mohammed and Angell (2003), Stewart (2006), Peeters, Rutte, van Tuijl, and Reyman (2006), and Kramer et al. (2014) provide further empirical support for the relationship between Big Five personality traits and team performance and effectiveness. While several studies linking Big Five personality traits and job performance have been the target of concerns regarding internal and construct validity (e.g., Hurtz & Donovan, 2000), the Big Five model remains an important tool for assessing the impact of team personality composition on the ability of teams to successfully complete their tasks while providing a satisfying work experience.

**Work design factors.** Work design factors are the set of structures and roles within a team that determine the allocation of tasks, responsibilities, and authority (Hollenbeck, DeRue, & Guzzo, 2004, p. 360). Research in organizational psychology and behavior has established empirical links between work design factors and team effectiveness and performance. Factors falling under this heading include member interdependence and team autonomy.

**Member interdependence** refers to the degree to which team members must rely on each other to carry out the team’s assigned tasks; team member interdependence is one of the key features that delineate work teams from work groups. Kozlowski and Bell (2003) highlight the importance of team interdependence in research on team effectiveness and performance, writing
that work not addressing the construct “has little relevance to building knowledge in the work
groups and teams literature” (p. 363). Teams exhibiting a high degree of interdependence display high-quality social processes, mutual learning, and a sense of shared responsibility with regard to performance outcomes (Wageman, 1995). Two types of team interdependence - task interdependence and outcome interdependence - have been the focus of especial research attention. Task interdependence is described as the degree to which team members cooperate, share resources, and work interactively to complete tasks (Wageman, 1995). For example, the degree of task interdependence between members of a golf team is quite low, while on basketball teams task interdependence is high. High task interdependence occurs when team members interact cooperatively and depend on each other for information, materials, and feedback (Stewart & Barrick, 2000); highly complex tasks often require large amounts of task interdependence (Van der Vegt & Van de Vliert, 2002). The pathways through which task interdependence are hypothesized to influence team effectiveness develop as team members work together. High degrees of task interdependence encourage increased levels of interaction among team members, and positive rapport may develop between members as they gain confidence in their ability to collectively achieve their goals (Courtright, Thurgood, Stewart, & Pierotti, 2015). Team effectiveness is related to team member satisfaction, and as team-level efficacy increases, the overall effectiveness of the team may be enhanced. Empirical links between task interdependence and team effectiveness have been observed in numerous studies, including Wageman (1995), Stewart and Barrick (2000), Gully, Incalceterra, Joshi, and Beaubien (2002).

Outcome interdependence is defined as the extent to which task accomplishment produces results that are important to or shared by team members (Shea & Guzzo, 1987, p. 26);
such results include both rewards (e.g., time off from work) and punishments (e.g., managerial reprimand). Team outcome interdependence functions to emphasize group contributions over individual effort (Courtright et al., 2015) and is hypothesized to influence team performance and effectiveness through the interaction between team members’ individual motivation and the nature of the team-level result. When team members are rewarded collectively for their performance on a task, a spirit of cooperation is fostered and team effectiveness may be enhanced (“sink or swim together”); rewards for teamwork offered at an individual level may negatively influence team effectiveness by creating atmosphere of competition (“you sink, I swim”) (Van der Vegt & Van de Vliert, 2002). As with many team-level constructs, the relationship between outcome interdependence and team effectiveness is complex. For instance, work by Beersma, et al. (2003) showed that competitive team environments increase the speed with which teams complete their work, while cooperative environments enhance the accuracy with which teams work. As with task interdependence, empirical links have been established between outcome interdependence and enhanced team effectiveness (Campion et al., 1993; Courtright et al., 2015; Van der Vegt & Van de Vliert, 2002; Wageman & Baker, 1997).

**Autonomy.** The extent to which teams and team members are able to control aspects of the work they do, and features of the environment in which they do that work, is an important consideration with regard to team task design. This freedom is codified in the construct of autonomy, which refers to the degree to which the task “provides substantial freedom, independence, and discretion in scheduling the work and in determining the procedures to be used in carrying it out” (Hackman & Oldham, 1980, p. 79). Autonomy is typically considered a positive feature of team task design, (van Mierlo et al., 2006) and features centrally in many models of team effectiveness (Campion et al., 1993).
Two types of autonomy feature prominently in the research literature: *team autonomy* and *individual autonomy*. *Team autonomy* is the amount of discretion and control a team is allowed in performing its assigned tasks (Langfred, 2000). Teams with a high degree of team autonomy may control such features of their tasks as schedules, pace, and deadlines; teams with limited team autonomy will have little input into the tasks they perform and how and when they perform them. Banker et al. (1996) describe an autonomy continuum, with *traditional work groups* having the least amount of autonomy and *self-designing teams* (teams with the freedom to organize their structure and environment and determine which tasks they will do) representing the opposite end of the spectrum. *Semi-autonomous work groups* have the freedom to manage and execute work functions, but must rely on external agents for support activities (e.g., quality assurance). *Self-managing teams* have the ability to regulate the pacing, means, and methods with which they work; self-managing teams are used widely in the workforce (Magpili & Pazos, 2017) and have been the focus of much research attention. Figure 1 displays the Banker et al. (1996) group autonomy continuum.

![Autonomy Continuum](image)

**Figure 1.** Group autonomy continuum (Banker et al., 1996).

*Individual autonomy* refers to the extent to which individual team members control features of their work; for example, members of teams with high individual autonomy may set their own hours and listen to music as they work, whereas individuals in teams with low individual autonomy may follow a rigid schedule and work in a tightly regulated environment. While both feature in many models of team effectiveness, team and individual autonomy exist
independently (Langfred, 2000); teams granted wide latitude in work-related decisions may nevertheless encounter limits on individual autonomy.

The impacts of both individual and team autonomy on team performance and effectiveness have been well studied. Warr (1994), for example, identified individual autonomy as a feature supportive of worker mental health, writing that job design factors such as decision-making latitude, job control, and participation in decision-making correlate positively with workplace satisfaction. Batt (2003) reported similar results. In a large empirical study, increased individual autonomy was linked to higher levels of worker satisfaction and employment security. Findings correlating team autonomy with increased levels of team effectiveness were also reported in Barrick and Stewart (2000), Langfred (2000), and van Mierlo et al. (2006). Relationships between team and individual autonomy and team effectiveness are not always positive, however. Barker (1993) described a process whereby teams granted a high degree of team autonomy may tightly restrict individual autonomy, reducing the overall level of satisfaction team members experience with their work; similar findings are discussed in Parker (2017). Langfred and Rockman (2016) discuss the conflict between increases in workers’ desire for individual autonomy and organizational needs for control; as with team-imposed limitations on individual autonomy, this tension has worked to limit worker satisfaction.

Intragroup factors. Intragroup factors are the set of relationships, behaviors, and processes that facilitate the day-to-day functioning of teams. Many intragroup factors are considered team emergent states. Team emergent states are group level constructs that evolve out of the interactions between team members (Jehn, Greer, Levine, & Szulanski, 2008). Relevant intragroup factors include team mental model and transactive memory.
Team mental models. For teams to succeed, team members should possess a shared vision of both the goal toward which the team is working and the means through which that goal is achieved; this understanding is captured in the construct of team mental models (TMM). On an individual level, mental models are organized knowledge structures that allow individuals to interact with their environment, draw inferences, and predict and explain the behavior of the world (Mathieu et al., 2000); mental models go beyond declarative knowledge to encompass the organized cognitive representation of that knowledge (Edwards, Day, Arthur, & Bell, 2006). Extending this concept to the level of the team, team mental models represent the shared organized understanding and representation of key elements of a team’s task and environment; TMM include shared understandings of the team task, knowledge of equipment and team members, and procedural and strategic knowledge (Mohammed & Dumville, 2001). TMM are considered a team emergent state that extends beyond the sum of individual team members’ knowledge (Klimoski & Mohammed, 1994). TMM provide team members a common understanding of who is responsible for which aspects of the team task and what is required to complete that task (Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Additionally, TMM allow team members to more effectively coordinate teamwork activities, adapt more easily to changing or difficult situations, and efficiently share information (Stout et al., 1999). While team members may between them possess highly similar understandings of what they are to do, the possibility exists that this shared information may be erroneous. Edwards, Day, Arthur, and Ball (2006) found that accuracy of TMM is a more robust predictor of team effectiveness than similarity of ideas.

The pathways through which TMM impact team effectiveness and performance are hypothesized to involve team communication and coordination. Teams in which robust TMM are
present are able to communicate more effectively, providing increased opportunities for team strategizing; such team-level planning in turn allows team members to more easily predict the information and resource needs of teammates, thus facilitating efficient teamwork processes (Mathieu et al., 2000). Teams that are able to effectively plan together have been identified as possessing more similar and accurate TMM than teams that cannot (Stout et al., 1999). Importantly, TMM enable team members to operate efficiently under conditions in which communication and coordination may be limited (Mathieu et al., 2008).

Cannon-Bowers and Bowers (2011) reported that TMM have a moderate effect size with respect team effectiveness and performance, and numerous studies have found empirical links between TMM and team functionality. Espevik, Johnson, Eid, and Thayer (2006), for instance, found that shared knowledge of team members (e.g., individual ability) contributed to team performance beyond the level of baseline operational skills. Marks, Zaccaro, and Mathieu (2000) studied the impact of team leader briefings on team effectiveness, finding that leader briefings contributed to development of TMM and had positive impacts on team performance. That TMM and team effectiveness may be positively impacted by cross-training (i.e., training in which each team member learns the roles and responsibilities of his or her teammates) was demonstrated by Marks, Sabella, Burke, and Zaccaro (2002).

Transactive memory. Closely related to the concept of team mental models is the notion of transactive memory (TM). As a construct, transactive memory was initially developed to help explain communication and memory-storage processes in romantic partnerships; on this level, TM consists of knowledge about what another person knows, coupled with the body of knowledge resulting from that understanding (Lewis, 2003, p. 588). For example, a spouse may not need to remember a family member’s birthday when knows that information is possessed by
her partner. At the level of the team, individual cognition combines to form a *transactive memory system* (TMS). Transactive memory systems are an emergent state of teams (Zhang, Hempel, Han, & Tjosvold, 2007) that represent a cooperative division of labor for learning, remembering, and communicating team knowledge which provides team members with quick access to each other’s specialized expertise (Lewis, 2004). Access to team member knowledge and expertise is hypothesized to enhance team functionality through increased utilization of team member resources and knowledge, creating a knowledge-holding system that is more complex and efficient than what is achievable on an individual level (Zhang et al., 2007). In addition to functioning as a repository of knowledge, TMS may reduce the cognitive load of each team member and reduce redundancy of member effort (Mohammed & Dumville, 2001). While similar to team mental models, the focus of TMS are the identification, distribution, and combination of member knowledge and expertise; team mental models represent knowledge of the team task environment and the shared mental representation of the function of the team.

Team transactive memory systems have been identified as an influence on team effectiveness and performance (Austin, 2003; Choi & Robertson, 2008; Lewis, 2004); a key aspect of this effect is the role played by TMS in the identification and utilization of team member expertise. TMS provide team members with an understanding of each other’s domain-specific knowledge, providing an expanded pool of expertise from which to draw. In turn, knowledge of member specialization facilitates the assignment of sub-tasks, enhancing team effectiveness by bringing the appropriate knowledge and skills to bear on the team task. Additionally, knowledge of who knows what provides team members opportunities to further develop their own areas of expertise. Identification of individual expertise limits the need for
teams to seek external assistance, thereby increasing work efficiency, and may serve to reduce the number of coordination miscues (Austin, 2003).

**Organizational Aspects of Triad Co-teaching**

**Co-teaching Triads as Work Teams**

A work team is a collective embedded in an organization that works toward a shared goal and whose task requirements necessitate a high degree of mutual interdependence and the freedom to regulate the manner in which group and individual tasks are performed. Members of teams often possess individual skillsets that differ from those of their teammates, with roles and responsibilities within a team being assigned contingent on individual expertise. The interdependent nature of team tasks requires that all members contribute effort, skill, and knowledge; as a result, team members depend on each other to perform their individual tasks in a satisfactory manner, and thus hold each other accountable for the work they perform. Team task work must conform to external standards of performance, but within those frameworks team members may have wide latitude with regard to the strategies, processes, and techniques they use to complete their assigned tasks.

The activities of Trinect co-teaching triads are congruent with those performed by work teams. Effective co-teaching requires teachers to work together to co-plan lessons; accordingly, triad members must participate in mutual planning sessions in a manner that ensures a satisfactory distribution of effort and expertise. Teachers are required to make decisions regarding the content, materials and activities, instructional strategies, and teacher behaviors they will use (Clough, Berg, & Olson, 2009), and while co-taught lessons are required to align with district standards, triads have a large amount of freedom with respect to the pedagogical choices they make. During co-instruction, triad members must collectively monitor student behavior and
manage classroom logistics while maintaining an individual awareness of the general flow of instruction and the activity of the other members. Congruent with the activities of work teams, STEM triad co-teaching is thus an interdependent activity characterized by a high degree of member autonomy. Similar to GK-12 teacher-fellow partnerships, a pronounced experience and expertise differential exists within Trinect co-teaching triads, and the adoption of roles and responsibilities will likely be related to member specialization.

Based on these considerations, Trinect STEM co-teaching triads meet the criteria of a work team. While the functions performed by a team are independent of its assigned classification, clear identification of team type allows comparison with research on similar types of groups (Vangrieken, Dochy, Rae, & Kyndt, 2013). Thus, analysis of specific task and relational characteristics of Trinect teaching triads may be undertaken from the perspective of teamwork theory. While many studies of co-teaching partnerships have provided detailed analyses of co-teacher interactions and the factors that support effective co-teaching relationships, few published studies have undertaken to integrate the activity of co-teaching into a unifying framework.

Team typology. Members of Trinect STEM co-teaching triads combine resources and individual expertise to plan and teach science and engineering lessons over the course of a 16-week semester. Triad members rely on each other to assist in instruction, monitor students, and be attentive to emergent logistical needs. Co-teaching teams may also have a great deal of latitude in choosing appropriate pedagogical strategies and instructional materials. As a practice, then, triad co-teaching is a highly interdependent task with individual and team autonomy. Considered together, these characteristics meet the criteria of a project team, described by Sundstrom et al. (2000) as a time-limited entity consisting of cross-functional members whose
disciplines often differ and who possess specialized skillsets. Project teams perform tasks requiring a considerable application of knowledge, judgment, and expertise (Cohen & Bailey, 1997). In STEM co-teaching triads, this characteristic manifests as the implementation of science content knowledge and pedagogical content knowledge, as well as the utilization of the “day-to-day” classroom experience of the cooperating teachers. Project team performance assessments are frequently based on supervisor-level evaluations and team-members’ self-reported feelings of satisfaction with team accomplishments and functionality (Cohen & Bailey, 1997). The performance of co-teachers is similarly assessed. School officials execute classroom observations, rating co-teachers on measures of professionalism that include classroom management, student progress, degree of observed collaboration, and observable impact of multiple professionals sharing instructional responsibilities (Gable, Mostert, & Tonlen, 2004; Magiera & Simmons, 2005; Murawski & Lochner, 2011). While co-teaching assessment instruments do not always solicit feedback regarding perceptions of the health of the co-teaching relationship, Salend, Gordon, and Lopez-Vona (2002) and Magiera and Simmons (2005) both indicate that reflection on the state of a co-teaching relationship should not be neglected.

**Triad Tasks**

Co-teaching requires teachers to work together to plan lessons, collectively deliver instruction while monitoring student behavior and logistical concerns, and assess student performance (Conderman & Hedlin, 2012; Murawski & Lochner, 2011). As described above, multiple task-types may be embedded within a team’s general function; in this instance, each aspect of co-teaching represents a discrete task. Subsequent paragraphs will situate each co-teaching element within Steiner’s taxonomy of tasks.
Co-planning. Co-planning science and engineering lessons likely requires triads to amalgamate individual experience, knowledge, and expertise. Guided by appropriate school district standards, during co-planning sessions triad members must determine and agree upon what will occur during the lesson, the instructional models to be used, the distribution of lesson roles and responsibilities, and measures of student performance (Pratt et al., 2017). The efficiency of planning sessions, however, may be complicated by the non-uniform distribution of pedagogical knowledge and expertise present in the triad. While the years of experience represented by triad cooperating teachers varies, they will in general have a great deal more classroom experience than the student teachers; both the cooperating teacher and student teacher groups will be far more experienced in the classroom than the engineering fellows. Thus, triad lesson plans are may likely be influenced by ideas provided by the cooperating and student teachers. However, as elementary teacher preparation in science and engineering may be limited (Banilower et al., 2013), the engineering fellows may provide content advice and experience with science and engineering practices and materials beyond what is known to their teammates. Tasks in which the outcome represents a combination of member resources and expertise are compensatory tasks; thus, it is appropriate to assign the general designation of compensatory task to the process of co-planning lessons. As sub-tasks may be assigned to individual triad members during planning sessions (e.g., researching an authentic context for an engineering lesson), the process of co-planning lessons will be further characterized as a divisible task. It should be noted, however, that this (and subsequent) task characterizations are somewhat provisional; circumstances may be such that while the general nature of a task remains intact, the distribution of member contributions may result in a combination of member effort different than what this analysis reports. For example, should circumstances warrant that the planning of a lesson be the
responsibility of a single individual, the task designation of co-planning shifts from compensatory task to a disjunctive task (i.e., a task whose success depends on the ability of a single team member).

**Co-instruction.** Lesson implementation that optimizes the expertise of teachers in co-taught classrooms is a great deal more complex than simply having one teacher deliver instruction while the other monitors student behavior, distributes materials, and assists individual students (Friend et al., 2010). Effective lesson implementation requires well-defined roles, an attentiveness to the activity of other co-teachers, and a willingness to let others perform tasks that one considers one’s own area of expertise (Rice & Zigmond, 2000). Cook and Friend (1995) discuss several widely used co-teaching models; although as described the models pertain to co-teaching pairs in special education settings, STEM co-teaching triads are encouraged to adapt these strategies for use in three-person co-teaching teams and are examined as such here. Each co-teaching strategy involves different combinations of teacher effort; thus, in terms of task theory each must be considered separately.

**One teach/two assist.** Research on co-teaching indicates that one teach/one assist is the model most frequently used by paired co-teachers (Mastropieri et al., 2005; Weiss & Lloyd, 2002). In the context of co-teaching triads, this model becomes one teach/two assist. In the one teach/two assist model, a single triad member is responsible for teaching the lesson, while the remaining members play supporting or observer roles; as both student teachers and engineering fellows have limited classroom experience, such an approach may be used to promote professional growth within these groups. As the lesson is taught by one person, the responsibility for meeting learning objectives rests with a single individual. Thus, triads employing the one teach/two assist model are performing a disjunctive task.
**Station teaching.** In *station teaching*, co-teaching team members divide instructional content into several sections; each section is taught by one team member in a separate area of the classroom, with student groups rotating through each station. Each triad member is responsible for implementing their portion of the lesson effectively, and the overall success of the lesson will be limited by the least well-performing team member; tasks of this nature are classified as conjunctive tasks.

**Parallel teaching.** *Parallel teaching* occurs when teachers separately teach small groups of students the same lesson. In triad co-teaching, for example, the class may be split into thirds, with each member leading the same hands-on activity. As in station teaching, each triad member is responsible for implementing their portion of the lesson effectively, and the overall success of the lesson will be limited by the least well-performing team member; thus, parallel teaching is also a conjunctive task.

**Team teaching.** In *team teaching*, all three triad members participate directly in the lesson. Team teaching roles may be explicitly identified prior to implementation, or they may evolve spontaneously according to the needs of the lesson. The spontaneous nature of team teaching may pose difficulties for teachers unaccustomed to sharing teaching responsibilities and may be difficult to achieve for novice co-teachers; for these reasons, team teaching has been identified as difficult to successfully enact (Cook & Friend, 1995; Reinhiller, 1996). Unlike the other co-teaching models, missteps and omissions made by one co-teacher may be identified and corrected by teammates in real time. As each triad member makes direct instructional contributions to the lesson, the extent to which a team-taught lesson is successful will be a function of average member ability. Tasks which represent an “average” team effort and that
include the possibility of real-time corrections are compensatory tasks; thus, lessons team taught by three co-teachers are representative of compensatory tasks.

**Two teach, one assist.** Two teach/one assist is a strategy unique to co-teaching triads and is not discussed in the literature. Teams employing this approach assign two co-teachers a lead teacher role while the third provides logistical and management support. A modified form of team teaching, the two teach/one assist model allows co-teachers to identify and correct errors and omissions in real time and reflects the averaging of co-teacher ability. As such, co-teaching teams using two teach/one assist approach are engaging in a compensatory task.

**Co-assessment.** Co-assessment refers to the processes of setting benchmarks for student learning and progress and actively assessing student work; co-assessment tasks may include setting learning goals, grading student papers, and evaluating laboratory work, as well as engaging in formative assessments during instruction. Conderman and Hedlin (2012) note that co-assessment practices occur as soon as co-teaching teams form, and continue during lesson planning, lesson implementation, and after completion of lessons or units. Accordingly, when situating co-assessment within Steiner’s taxonomy, two time frames must be considered: (1) prior to lesson implementation, during which time triads work toward mutual understanding of individual assessment philosophies and discussing benchmarks for student progress, and (2) after lesson implementation, when the actual evaluation of student work occurs. Prior to lesson implementation, the sharing of perspectives and philosophies with the aim of achieving mutual understanding and the setting of progress benchmarks are tasks in which each member may have something to contribute, regardless of specific expertise; further, gaps in knowledge of and experience with assessment may at this stage be covered by the more experienced members of the triad. Thus, the discussion of assessment philosophies and determination of assessment
practices in which gaps in experience may be addressed represents a compensatory task. Following lesson implementation, the responsibility for evaluating student work may reside with either a single individual or the co-teaching team as a whole. The first instance is not a team task, and as such falls outside the purview of Steiner’s taxonomy. Determination of the Steiner task type in the second case hinges on the distribution of assessment responsibilities. For example, grading a class set of worksheets split equally among the three triad members would represent an additive task; in this case, each co-teaching team member would play an equal role in the assessment process. However, should the team make the decision to collaborate and evaluate each worksheet collaboratively, assessment would exemplify compensatory task.

Team Effectiveness of Co-teaching Triads

Trinect co-teaching triads are exemplars of project teams. Project teams are often evaluated on both task performance and the extent to which team member interactions support positive intra-team relationships. With regard to co-teaching, published literature serves to provide guidance on how to observe and evaluate co-teaching pairs (e.g., Magiera-Simmons, 2005; Murawski & Lochner, 2011; Salend, Gordon, & Lopez-Vona, 2002), but little has been written in support of co-teaching triads. Further, effective teams do more than accomplish their work in an exemplary manner; in addition to successful task performance, effective teams meet the socioemotional needs of team members. While some authors acknowledge the role of team member relationships and satisfaction (e.g., Salend, Gordon, & Lopez-Vona, 2005), these two strands of team success are not unified. Thus, with regard to the performance evaluation of Trinect co-teaching triads, the need exists for a framework that addresses the two-dimensional nature of team success and that can account for the task characteristics and complexity of member activities and interactions in a three-person group.
Team effectiveness is a value-laden construct that captures the ability of teams to perform their work successfully while meeting the socioemotional needs of their members. As teams carry out a wide variety of tasks, for each type of team the need exists for a specific set of criteria against which to assess team effectiveness. A team effectiveness framework applicable to Trinect co-teaching triads will be described below.

**Team performance.** Trinect co-teaching triads are tasked with teaching substantive, reform-based engineering and science lessons. As such, the performance aspect of team effectiveness centers on the quality and content of co-taught lessons and the collaborative nature of co-teaching. Triad taught lessons should align with district science and engineering standards, and lesson content should be congruent with the developmental needs of students. Lesson implementation should reflect knowledge of research-supported practices in science and engineering education; such practices include use of the inquiry and learning cycle models of science teaching, providing opportunities for students to surface and discuss prior knowledge of relevant science ideas, and engaging in rigorous conceptual development of targeted material. Further, the presence of an engineering graduate student should noticeably impact science and engineering instruction; indicators of this involvement include rich discussion of science/engineering content at a level more advanced than what would be achievable by a non-science expert and substantive hands-on laboratory and field experiences. In addition, the presence of multiple teachers in a single classroom would be expected to result in increased individual attention and assistance to students, fewer disruptions from student misbehavior, and an increased number of student-teacher interactions.

The one teach/one assist co-teaching model occurs when one co-teacher assumes the role of lead teacher, while the other functions in an assistant or observer role; while in co-teaching
Triad member relationships. The relationships between team members and the impact of these relationships on the continued functioning of the team are the second dimension of team effectiveness. Paired co-teaching partnerships are known to be supported by positive personal relationships (Rice & Zigmond, 2000; Scruggs et al., 2007), and member relationships are anticipated to influence the performance of co-teaching triads as well. Effective co-teaching triads would show evidence of strong interpersonal relationships, including friendliness and collegiality, respect for each other’s areas of expertise, mutual supportiveness, and indicators that each team member has a voice in making pedagogical decisions. Salend, Gordon, and Vona-Lopez (2002) write that co-teacher perceptions of relationship issues may be solicited through...
written reflections and discussion with evaluators. Hackman (1987) notes that member relationships are a factor in the continued ability of the team to work together. The continued viability of triads that experience significant degradation of member relationships pursuant to personality conflicts, differences in approach to pedagogy, management, and assessment, or extenuating external circumstances (e.g., pressure from research advisors, family issues) may be at stake.

**Factors that impact triad team effectiveness.** Studies have identified a range of factors that promote positive co-teaching outcomes; few, however, have undertaken such research from the perspectives offered by teamwork theory. Trinect co-teaching triads represent the broader classification of project team and adoption of this point of view is therefore warranted. Subsequent paragraphs will investigate the issues of administrative support, team composition, task design, and intragroup processes as pertain to co-teaching triads.

**Administrative support.** Work teams are embedded in organizations, and the institutional context in team functions may influence team effectiveness. Organizational factors that have been observed to impact team effectiveness include support for the work of the team and opportunities for team training (Cohen & Bailey, 1997; Sheard & Kakaadse, 2000). Congruently, the need for institutional support for co-teaching from school building and school district administrators has been well-documented (e.g., Pratt et al., 2017; Trent et al., 2003). School officials may offer support to co-teachers by making space in daily schedules for common planning time and communicating with parents and staff about the goals of the Trinect program. GK-12-programs have paired classroom teachers with STEM graduate students, and thus school officials may have some familiarity with this approach; however, the Trinect approach is unique and may require and increased amount of communication between
administrators, parents, and school staff. Additionally, school administrators may be asked for permission to rearrange the host classroom schedule to accommodate collaborative planning time or extended hands-on activities. The use of engineering graduate students has further implications for administrative support (Brewer et al., 2013). Although the engineering fellows remain active in their research work, their participation in Trinect limits their availability to fully engage in these activities. An understanding of Trinect project goals by university engineering faculty is therefore crucial.

**Team composition.** As noted above, team composition factors pertain to the structural and demographic characteristics of teams; included among team composition factors are team size, demographic diversity, and team member personality.

**Parity.** While the direct impact of team size on team effectiveness has been difficult to understand (Cannon-Bowers & Bowers, 2011; Kozlowski & Bell, 2003), effects related to team size parity have been found to operate within work teams. Work by Simmel (1950) and Caplow (1968) showed that among three-person groups, the formation of “two against one” subgroup coalitions is a regular occurrence. Subgroup formation was hypothesized to be driven by perceived differences in social between group members. This is a specific instance of more general work by Hare (1981), who observed that teams with more than two members undergo subgroup formation that is a function of the parity of the size of the team.

**Coalition formation.** It is anticipated that this effect will exist within Trinect co-teaching triads. French and Raven (1959) describe five bases of social power that may drive coalition formation within triads. *Reward power* is a social influence based on the real or perceived expectation that one person may provide a reward to another; similarly, *coercive power* arises when there exists an expectation of punishment of one person by another. *Expert power* is based
on the perception that a person possesses a high degree of expert knowledge or skill in a particular area. *Legitimate power* arises from the existence or perception of a sanctioned figure of authority. *Referent power* results from the charismatic attraction of one person to another. While a detailed analysis of all cases is beyond the scope of this review, a summary examination of potential power imbalances within co-teaching triads is provided below.

Regardless of the other roles held by the cooperating and student teacher, the student teaching experience is significantly impacted by the evaluative responsibility of the cooperating teacher (Anderson, 2007). Student teachers value positive reviews from their cooperating teachers (Beck & Kosnick, 2002) and pursuit of such may heavily influence nascent attitudes and beliefs and affect pedagogical decisions (Clarke, Triggs, & Nielsen, 2014; Seker & Deniz, 2016). Cooperating teachers may thus wield *reward power* over the student teachers. Conversely, student teachers may engage in activities they feel will mitigate the perceived consequences of a negative review; in this case, cooperating teachers may wield *coercive power*. In either of these cases, student teachers may feel pressure to engage in pedagogical activities that are misaligned with their understanding of what constitutes sound teaching practice. This effect may be particularly relevant to science instruction, an area in which inservice teachers are known to encounter challenges. As a result of the real or perceived wielding of reward or coercive power by the cooperating teachers, student teachers may bond more tightly with their cooperating teacher than with the engineering fellow as a means to either receive a positive review or avoid a negative review. On the other hand, student teachers may feel intimidated by their cooperating teachers with regard to the latter’s position of authority over them and may form closer bonds with their engineering fellow.
Expert power arises in instances where one or more individuals either possess or are perceived to possess a high degree of expert skill and/or knowledge in a particular area. Within Trinect co-teaching triads, two centers of expert power may exist. First, cooperating teachers have extensive experience teaching in elementary school classrooms relative to their teammates and may be viewed by the other triad members as experts in pedagogy. Cooperating teachers possess undeniable expertise about the school (including resources, facilities, support staff, leadership, and policies) and the students in the classroom, particularly for triads participating in the second semester of the school year. Cooperating teachers may thus be able to influence team decision-making directly, through recourse to their years of experience or position as an employee of the school, or indirectly, as the student teachers and engineering fellows may summarily defer to that experience and position. Engineering fellows possess a high level knowledge of engineering, science, and mathematics and may be considered content experts by their teammates. Engineering fellows may influence team activities and decision-making in a manner similar to that of the cooperating teachers, either through direct recourse to knowledge or through the deference of their teammates. Additionally, science and engineering knowledge may be perceived as “more valuable” than knowledge of teaching and students (Labaree, 2004). Deference to the knowledge and experience of the engineering fellows may also occur on these grounds.

Trinect co-teaching triads do not have a formal leadership structure. However, pursuant to their role in the classroom, cooperating teachers may viewed as a figure of legitimate authority within their triad and may thus be able to wield legitimate power. Cooperating teachers are held legally held responsible for what occurs within their classrooms, and acknowledgement of such
may allow cooperating teachers to exert a disproportional influence on team decision-making and pedagogical activity.

*Referent power* arises out of a charismatic attraction between individuals. Irrespective of other roles played by a team member, personal agreeability may be able to influence team decisions and activity. In Trinect co-teaching triads, referent power may be exerted by any individual and may amplify or inhibit other forms of influence they possess and may interfere constructively or destructively with power wielded by their teammates.

The bases of social power described by French and Raven (1959) may be used to model coalition formation within Trinect co-teaching triads. For instance, a student teacher may be especially outgoing and friendly, allowing her to wield referent power over the engineering fellow; simultaneously, the student teacher may feel threatened by the potential of a negative review by her cooperating teacher. Thus, the engineering fellow and student teacher may bond tightly and both openly and tacitly resist the influence of their cooperating teacher. Interpersonal dynamics are complex, however, and no predictive models of human interactions in triad settings exist. Further research is needed to more fully understand the interactions between social power and expertise in co-teaching triads.

*Demographic diversity.* The influences of demographic diversity on team performance have not been firmly established (Horwitz & Horwitz, 2007; Mannix & Neale, 2005). However, demographic factors that influence team effectiveness are speculated to exist within Trinect co-teaching triads. One such factor is country of origin. Findings from research funded by the Organization for Economic Cooperation and Development (OECD, 2009) indicate that country of origin may influence teachers’ approach to pedagogy. In this study, teachers were surveyed with questions relating to their preference for constructivist or direct instructional methods of
teaching. Findings from this study indicate that preference for a particular model is significantly
influenced by country of origin. Co-teachers bring with them individual perspectives on
teaching and learning, and the compatibility and mutual understanding of these views may be
predictive of co-teaching success (Pratt, 2014; Rice & Zigmond, 2000). As universities, and
departments of engineering in particular, often enroll persons of diverse cultural backgrounds,
potential differences may exist with respect to approaches to education in culturally diverse
triads; these differences in perspective may constructively or destructively interfere with triad
effectiveness. Further findings from OECD (2009) show adoption of a constructivist or direct
instructional approach may also be associated with gender. For the participants in this study,
female teachers were more likely to adopt constructivist perspectives, while male teachers
favored the direct transmission model.

Personality. The impact of team member personality on team effectiveness has been
well-studied (e.g., Kramer, Bhave, & Johnson, 2014; Mount, Barrick, & Stewart, 1998; Neuman,
Wagner, & Christiansen, 1999). Results from these studies indicate that both team member
personality and the distribution of personality traits within a team can influence team
effectiveness, but also that these effects are complex and difficult to isolate. Results of studies of
co-teachers indicate that the impact of personality is both noticeable and highly valued among
factors related to positive co-teaching outcomes (Rice & Zigmond, 2000). Thus, it is speculated
that relationships between members of Trinect co-teaching triads will also be mediated by
personality characteristics. Additionally, individual personality characteristics may interact with
the bases of social power described above. For instance, a moderately introverted student
teacher may become even more so when involved in a coercive power relationship with their
cooperating teacher. Kohler-Evans (2006) noted that differences in personality may manifest in
both positive and negative ways during instruction; this potential may be heightened in three-
person co-teaching teams.

**Task design factors.** Work design factors are the set of structures and roles within a
team and its environment that determine the allocation of tasks, responsibility, and authority
(Hollenbeck, Guzzo, & Shea, 2004). Work design factors of particular relevance for Trinect co-
teaching triads include team interdependence and autonomy.

**Team interdependence.** *Team interdependence* refers to the degree to which teams have
the authority to regulate features related to their task and work environment. Two types of team
interdependence discussed in the research literature are of particular relevance for Trinect co-
teaching triads: *task interdependence* and *outcome interdependence*.

*Task interdependence* refers to the extent to which team members engage in cooperation,
communication, and resource sharing to perform their assigned tasks. Task interdependence is
often proportional to task complexity (Van der Vegt & Van de Vliert, 2002). As triad co-
teaching in an elementary school classroom had been identified as a compensatory task, the
degree of success achieved by a triad is proportional to the average ability and effort of
individual triad members. In order to optimize effectiveness, areas in which particular triad
members show weaknesses must be balanced by the strengths of others; such activity is highly
reflective of increased levels of task interdependence. In addition, high task interdependence has
been linked to enhanced team effectiveness through a need for close collaboration and positive
social skills (Courtright, 2015). Triads whose members support each other in their work are
therefore more likely to form close bonds and operate at higher levels of team effectiveness than
those whose members do not engage in supportive work practices.
In order to optimize the impact of triadic co-teaching, triad members must collaborate closely, share knowledge and skill appropriately, and clearly define roles and responsibilities. When co-planning, this is achieved through a substantial contribution of effort by all teachers (Conderman, 2011). During collaborative planning teachers share ideas and resources and assign lesson responsibilities; lessons will likely not reflect the presence of multiple teachers if member input is imbalanced. Thus, collaborative planning is an activity that reflects a high degree of task interdependence.

While teaching lessons, each co-teacher must play a substantive role in delivering instruction (Cook & Friend, 1995; Simmons & Magiera, 2007). The five foundational co-teaching models described by Cook & Friend (1995) require varying degrees of task interdependence. The one teach/one assist approach, or one teach/two assist in the case of co-teaching triads, requires substantial effort on the part of only one team member; team teaching, on the other hand, requires a high degree of coordination between co-teachers and thus is highly task interdependent. While alternative teaching, parallel teaching, and station teaching do not require teachers to directly work together, the success of the co-teaching team depends on performance of each member individually; these models of co-teaching therefore also exemplify high task interdependence. In addition, authentic co-assessment requires the input of all co-teachers (Conderman, 2012). While triad members may not at all times work together to assess student understanding, a team-level agreement of how work will be assessed and grades assigned is again reflective of a highly task interdependent activity. Thus, triad co-teaching is highly task interdependent during each phase of instruction.

*Outcome interdependence* refers to the extent to which task accomplishment by a team produces results that are important to or shared by all team members (Shea & Guzzo, 1987, p.
26). As co-teaching triad members likely care about the performance of their students, the degree of success achieved by their students is important to all members of a co-teaching team. Further, co-teachers are held jointly accountable for their performance as a team (Cook, 2004), and thus the degree of success achieved by a co-teaching team is shared by all members. As such, triadic co-teaching is an activity characterized by a high degree of outcome interdependence.

**Organizational autonomy.** Autonomy in the context of work teams refers to the ability of teams and team members to regulate features of their collective task and work environment. Forms of organizational autonomy relevant to Trinect co-teaching triads are *team autonomy* and *individual autonomy*.

*Team autonomy* refers to the amount of discretion and control a team is allowed in performing tasks assigned by the organization (Langfred, 2000). Clough, Berg, and Olson (2009) stress the importance of basing pedagogical decisions on knowledge of students and principles of learning; the co-teaching literature echoes this notion (Cook & Friend, 1995). Trinect co-teaching triads teach engineering and science lessons, with learning outcomes that must align with school district science and engineering standards. Within the bounds of learner ability and district standards, however, triads have wide latitude to choose the co-teaching models, engineering and science activities, and methods of instruction, classroom management, and assessment they feel will be most beneficial to their students. Unless they have negotiated a rearrangement of their daily schedule, co-teaching triads must teach their lessons in accordance with the building master schedule; triads may thus encounter limitations with respect to the amount of time available to teach their lessons and the times at which they will teach them. Banker et al. (1996) described *semi-autonomous work teams* as teams that have a moderate
amount of authority with respect to regulation of major team functions; while semi-autonomous work teams may regulate some aspects of their task and environment, other characteristics are defined by external agents. As Trinect co-teaching triads face constraints related to content, pedagogical techniques and strategies, and scheduling, they will thus be considered a semi-autonomous work team.

*Individual autonomy* describes the ability of individuals to alter features of their task and work environment. Trinect triad members face constraints related to their school environment. Working hours for cooperating teachers are set by contract with the school district, with student teachers and engineering fellows expected to follow similar hours. In addition, triad member dress and general comportment must conform with behavioral standards and the legal requirements related to working in schools. Team member relationships may further impact individual autonomy, with team members able to exert influence over one another based on the real or perceived power relationships described by French and Raven (1959). In general, then, the individual autonomy in Trinect co-teaching triads may be somewhat limited.

**Intragroup factors.** Team members work together to complete tasks, and in so doing engage in a great deal of interpersonal interaction. *Intragroup factors* relate to the set of relationships, behaviors, and processes facilitating the day-to-day functioning of the team. Salient intragroup factors for co-teaching triads are *team mental models* and *transactive memory systems*.

**Team mental models.** Team mental models (TMM) relate to the establishment of common understandings between team members related to the team task, task environment, and what is needed to accomplish the task. Congruencies exist between research on shared mental models and research on co-teaching. Hollenbeck, DeRue, and Guzzo (2004), for instance,
observe that effective team planning helps strengthen TMM, leading to increased communication efficiency and team coordination.

Mathieu et al. (2000) describe four types of team mental models; these are common understandings related to work-related technology, task strategies and procedures, team interactions, and team member characteristics. Technology TMM refer to shared understandings of the technologies teams use and how they relate to the functions of the team. With respect to co-teaching triads, included here are classroom items such as computers, projectors, and their interfaces, educational software and applications, and laboratory equipment, including its use, safety features, and possible contingencies. As members of co-teaching triads possess levels of experience with classroom teaching that differ between them, familiarity with classroom technologies may vary between members. Team performance may be enhanced when members share their knowledge and experience with classroom technology, as each member will know how to use each item efficiently and will be less likely to encounter technology-related obstacles.

Task-related TMM pertain to knowledge about how team tasks are accomplished in terms of procedures, task strategies, likely contingencies, and environmental conditions. These may be examined from the perspective of co-planning, co-teaching, and co-assessment. Within co-teaching triad planning sessions, indicators of task-related TMM include the degree agreement reached by the team regarding how to plan lessons, what content, materials, and methods will be used during the lesson, and triad member roles and responsibilities during the lesson. With respect to co-instruction, team mental models related to pedagogical approach may exist. Many university-level engineering programs often take a single-subject, direct instruction approach based on the “direct transmission” model of learning (Felder, Woods, Stice, & Rugarcia, 2000). Without a reliable set of pedagogical alternatives, the majority of instruction delivered by
engineering fellows may be of this nature (Smagorinsky & Barnes, 2014), which may contrast sharply with the philosophical perspectives of the cooperating and student teachers. While differences in pedagogical approach between triad members may be unavoidable, such disparities may result in team mental models that are less robust than what would occur if all members shared similar perspectives.

Also categorized as a task-related team mental models are the science and engineering content knowledge and pedagogical content knowledge needed to teach lessons. As not all members of a co-teaching triad will possess the same level of understanding of content to be taught, in order to effectively co-deliver instruction, a minimum level of shared content knowledge overlap is essential. Although levels of implementation may vary between individuals, the pedagogical strategies and techniques used during the lesson should be known and practiced by all members of the co-teaching team. Similarly, effective lesson delivery is dependent on a common understanding of what content will be taught, the roles and responsibilities of each team member during the lesson, and how student understanding and progress will be assessed.

*Team interaction* team mental models relate to the manner in which team members interact and relate to each other. Hollenbeck, DeRue, and Guzzo (2004) emphasize the importance of team member interactions, writing that generic teamwork skills often have a larger impact on team effectiveness than the knowledge and skill individuals bring to their teams. This includes interdependencies between team member roles and responsibilities and channels of communication. Co-teaching functions more efficiently when roles and responsibilities are clearly defined and assigned according to individual knowledge and skill (e.g., Bouck, 2007). Shared understanding of which team member is responsible for particular co-teaching functions
removes from members the cognitive load of maintaining real-time awareness of who is doing what and alleviates the concern that crucial aspects of the lesson or planning session may be missed.

Knowledge of team members constitutes the final team mental model. In this context, knowledge of team members includes specific information related to characteristics such as member personality traits, co-teaching strengths and weaknesses, and areas of specialization. Such awareness is critical in co-teaching teams, as it assists team members in tailoring behavior with regard to what teammates are expected to do (Mathieu et al., 2000). Many research and practitioner articles relating to co-teaching advocate for ongoing discussion of perspectives on education, classroom management, and assessment; such discussion represents the creation and maintenance of team interaction team mental models.

**Transactive memory.** Team transactive memory is specific knowledge of what each member of a team knows, coupled with the associated body of metaknowledge (Lewis, 2003). Transactive memory systems (TMS) allow team members to remain current on who knows which things, channel incoming information to the appropriate person, and provide strategies for accessing that information (Mohamed & Dumville, 2001). Additionally, TMS allow team members to trust the reliability of information held by teammates (Zhang et al., 2007). Team transactive memory systems specifically focus on utilizing and integrating distributed expertise (Lewis, 2003).

Team transactive memory systems are particularly relevant to co-teaching triads composed of members with varying levels of teaching experience and content knowledge. Knowledge of which team members possess certain information facilitates the assignment of team roles and responsibilities. Research on GK-12 triads indicates that teachers and STEM
graduate students adopted roles related to individual skillsets (Bledsoe et al., 2004). Teachers leaned toward roles related to pedagogy and classroom management, while teaching fellows enacted roles related to curriculum planning and dissemination of content knowledge; similar arrangements may exist within Trinect co-teaching triads. TMS further provide more easily accessible domain-specific knowledge. In this instance student teachers and cooperating teachers may turn to the engineering fellows for questions related to science and engineering content knowledge and philosophical perspectives, while the cooperating and student teachers may be centers of pedagogical information and knowledge of students relative to the engineering fellows. Importantly, both classroom and student teachers may play a role in monitoring the level of developmental appropriateness of content and lesson ideas forwarded by the engineering fellows. Similar to team mental models, team transactive memory systems may be facilitated by planning and training together (Mohammed & Dumville); thus, the activities of collaborative planning and mutually-attended professional development facilitate the creation and maintenance of team transactive memory systems.

**Conclusion**

The purpose of this study was to create a conceptual framework through which to better understand the functionality of Trinect co-teaching triads. Empirical and theoretical results from foundational areas of co-teaching research and small group behavior were reviewed, compared, and synthesized in support of this goal. Trinect co-teaching triads exemplify the characteristics of *work teams* (Banker, Field, Schroeder, & Sinha, 1996); in particular, science and engineering co-teaching triads were classified as *project teams* (Sundstrom, McIntyre, Halfhill, & Richards, 2000). Trinect co-teaching triads engage in a variety of instructional tasks, including activities related to collaborative planning and implementation of lessons. Team task typologies provide a
theoretical lens with which to understand team member effort and resource sharing during team task performance. In this paper, triad co-teaching was identified as a *compensatory task* (Barrick, Stewart, Neubert, & Mount, 1999); compensatory tasks are those in which the strengths and weaknesses of team members compensate for one another to produce an overall mean level of team performance. Members of Trinect co-teaching triads represent a wide range of experience with teaching in elementary schools; areas in which member is weak, such as classroom management, may be compensated by another triad member who is strong in that area. Factors that may impact the team effectiveness of Trinect co-teaching triads include country of origin, social power disparities related to member educational and professional background, and team member personality characteristics (French & Raven, 1958; Kramer, Bhave, & Johnson, 2014; OECD, 2009). While co-teaching triads have wide latitude to choose the content, materials, and activities they will use during their co-taught lessons, they are bound school district science standards and the developmental capabilities of young science learners; in this sense, Trinect co-teaching triads may be considered *semi-autonomous work teams* (Banker et al., 1996). Triad team effectiveness may be promoted through the formation and maintenance of shared cognitive representations of the co-teaching task; such representations may include mutual agreement regarding approaches to pedagogy, shared understanding of lesson content, and shared knowledge of educational technology.

**Further Research**

While relationships between co-teaching pairs have been well-studied, little is known about the manner in which co-teaching triads function. In order to better understand triadic co-teaching in the context of the classroom, further research is needed in the following areas. First, several well-known co-teaching models are used by paired co-teachers. What, if any, novel co-
teaching models are employed by co-teaching triads? Discussed in this analysis are factors related to the effectiveness of co-teaching pairs. To what extent do these factors play a role in determining the team effectiveness of co-teaching triads? Further, what new factors, if any, may be unique to co-teaching triads? A critical element of successful co-teaching relationships is the ability to engage in effective co-planning. In what ways do co-teaching triads engage in collaborative planning, and in what ways are these similar to and different from the methods used by co-teaching pairs? Team mental models and transactive memory systems have been well-studied in many contexts, but little is known about the presence of these knowledge structures in co-teaching relationships. What evidence exists for the presence of shared mental models and team transactive memory systems in co-teaching triads? Finally, members of teams often adopt or are assigned roles related to individual areas of interest or specialization. In what ways, if at all, are instructional roles and responsibilities delegated in Trinect co-teaching triads?

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CHAPTER 3. TEAM MEMBER ROLE DISTRIBUTION IN SCIENCE AND ENGINEERING CO-TEACHING TRIADS

ABSTRACT

Co-teaching triads composed of a grades 3-5 cooperating teacher, a student teacher, and an engineering graduate student participated in a 16-week science and engineering professional development program. While paired co-teaching has been well-studied in a variety of contexts, little is known about the functioning of co-teaching triads. In particular, the roles played by members of co-teaching triads during collaborative lesson planning and implementation activities have not been studied. For this study, co-teaching triads were observed during collaborative planning and teaching. Data collected during these observations were analyzed in coordination with participant interviews and survey responses to identify the roles triad members played within their group. Roles adopted by triad members were Experienced Teacher, Steward of Developmental Appropriateness, STEM Content Resource, STEM Curriculum Developer, Novice Teacher, and Bringer of New Ideas. Patterns of role adoption were observed across triads. Student teachers frequently held lead teacher roles related to their status as preservice teachers and were supported by their cooperating teacher and engineering fellow teammates. Issues related to the role of advanced content knowledge in elementary school science and engineering education were observed in several triads.

Introduction

Trinect co-teaching triads are tasked with collaboratively planning and teaching lessons. To accomplish this, participants engage in co-teaching. Co-teaching occurs when multiple teachers plan lessons, deliver instruction, and assess student work for a single group of students.
in one location (Cook & Friend, 1995; Murawski, 2003; Friend, Cook, Hurley-Chamberlin, & Shamberger, 2010). By combining individual knowledge and skill, co-teachers may create a learning environment that goes beyond what is achievable by a single teacher (Murawski & Lochner, 2011).

Co-teaching dyads have been extensively studied in a variety of contexts and a great deal is known about how paired co-teachers approach lesson planning and implementation and the institutional and interpersonal factors that support positive co-teaching outcomes (Bacharach, Heck, & Dahlberg, 2010; Murawski & Swanson, 2001; Scruggs, Mastropieri, & McDuffie, 2007; Rice & Zigmond, 2000; Walther-Thomas, 1997). However, little is known about the manner in which co-teaching triads operate. In particular, the roles held by member of co-teaching triads have not been studied. Among paired co-teachers, effective lesson planning and implementation are known to be supported by clearly defined roles (Dieker, 2001; Fennick & Liddy, 2001; Kohler-Evans, 2006). Poorly defined roles invite confusion as co-teachers negotiate role responsibilities in real time (Bledsoe, Shieh, Park, & Gummer, 2004), and may result in an imbalance in teacher authority (Hang & Rabren, 2009) and negative impacts on students (Rice & Zigmond, 2000). Bledsoe et al. (2004) found that participants in GK-12 partnerships held roles related to their individual areas of specialization. Similar to GK-12 teacher-fellow partnerships, within Trinect co-teaching triads an imbalance of pedagogical skill and science and engineering content knowledge exists, and the purpose of this study was to better understand how the roles enacted by members of Trinect co-teaching triads helped them negotiate this imbalance.

This study investigated the roles held by members of Trinect co-teaching triads through a multiple case study approach (Creswell, 2013) that involved analysis of participant interviews and observations of triad planning meetings and co-taught lessons. Triad member roles were
identified by their actions and statements during collaborative planning meetings and co-taught science and engineering lessons and through analysis of participant interviews. This study has the potential to advance the field of teacher education through its examination of a unique approach to co-teaching and application of teamwork theory to the functioning of triadic co-teaching teams.

**Literature Review**

**Co-teaching as a Pedagogical Approach**

As a general approach, co-teaching traces its roots to school reform efforts of the 1950s and the open-plan school model of the 1960s (Friend & Reising, 1993). In contemporary education, co-teaching is most frequently associated with special education (Badiali & Titus, 2010; however, as a general strategy co-teaching been successfully employed in general education content area teaching (e.g., Cacciatore & Morey, 2017; Moorehead & Grillo, 2013) and pre-service teacher education (e.g., Bacharach, Heck, & Dahlberg, 2010; Murphy, Beggs, Carlisle, & Greenwood, 2004). Co-teaching has been the object of intensive research, and although findings regarding student outcomes in co-taught classes have been inconclusive (Cook et al., 2011; Murawski & Swanson, 2001; Volonino & Zigmond, 2007; Zigmond & Magiera, 2001), the practice enjoys widespread popularity in the United States and in international classrooms (Gable, Mostert, & Tonelson, 2004; Rice & Zigmond, 2000).

**Elements of co-teaching.** Murawski (2003) writes that a fully formed co-teaching relationship consists of three elements: *co-planning, co-instruction,* and *co-assessment.* During *co-planning,* co-teachers work collaboratively to plan and implement shared curricula and instructional methods in support of agreed upon student goals and outcomes (Vangrieken, Dochy, Raes, & Kyndt, 2013). Co-teachers discuss what content will be taught, the strategies and
techniques used to teach that content, and who will be responsible for which aspects of the lesson (Pratt et al., 2017). The time and ability to plan together is frequently cited by teachers as one of the most important elements of a co-teaching relationship (Bacharach, Heck, & Dahlberg, 2008; Kohler-Evans, 2006); conversely, co-teachers often feel that lack of co-planning is a serious challenge to effective co-teaching (Pratt et al., 2017).

Co-instruction occurs when co-teachers collaboratively implement co-planned lessons; authentic co-teaching requires that both teachers be substantively involved in teaching the lesson, and is more than a “teacher and assistant” relationship (Ploessl, Rock, Schoenfeld, & Blanks, 2010). The involvement of multiple teachers in a single lesson means that instruction should be substantively different than what would occur with a single teacher (Murawski & Lochner, 2011). Cook and Friend (1995) outline five co-teaching structures: one teach/one assist, alternative teaching, parallel teaching, station teaching, and team teaching. Clough, Berg, and Olson (2009) stress the importance of basing instructional decisions on learner characteristics, and the co-teaching literature echoes this notion. Co-teaching models should be chosen based on student and teacher characteristics, the needs of students, and elements of the co-teaching environment (e.g., arrangement of student desks) (Cook, 2004). Co-teachers may discuss these considerations during collaborative planning time (Cook & Friend, 1995). Keely (2015) observes that choices regarding co-teaching models have important implications for instruction and students’ perception of their teachers. The one teach/one assist model, for instance, may promote the perception that the lead teacher is the “real” teacher, with the assisting teacher being invested with a lesser amount of classroom authority (Embrey & Kroeger, 2012).

During co-assessment, co-teachers reflect upon the effectiveness of their teaching efforts, assess student work, and use this information to make instructional decisions (Conderman &
Hedlin, 2012). Co-teachers have at their disposal many of the same evaluative techniques as do single teachers (e.g., formative in-class assessments, formal exams), but bring with them individual perspectives regarding the meaning of assessment and how it is to be implemented (Murawski, 2003). To avoid conflict, co-teachers are encouraged engage in ongoing discussion of the meaning and practices of student assessment (Murawski & Dieker, 2008).

**Co-teacher roles.** Co-teaching is predicated on the notion that the integration of the knowledge, skill, and experience of participant teachers will produce a classroom environment not achievable in a solo-taught classroom (Murawski & Lochner, 2011), thus enhancing the overall student experience. To create such an environment, co-teachers each play different roles within the co-teaching relationship. *Roles* are sets of behaviors typical of people in certain social contexts and describe what individuals are supposed do, how they are expected to act, and how their work relates to what others are doing (Levi, 2007; Johnson & Johnson, 2003). Within groups, roles help ensure that task behaviors are appropriately interrelated so that group goals may be accomplished (Johnson & Johnson, 2003); as well, group roles assist in defining expectations and responsibilities, facilitating group coordination by identifying who is expected to do what (Forsyth, 2014). Role assignment within groups may occur formally or informally. Formal assignment occurs when a role is deliberately assigned to a particular group member, either by a member of the group or by an external agent (Brown, 2000; Forsyth, 2014). Formal role assignments are often based on an individual’s qualifications relative to the task to be performed, which may allow the group to operate more efficiently (Levi, 2000). Informally held roles are those adopted by group members based on individual skills and interests but are not explicitly recognized by the group (Forsyth, 2014). Two broad categories of group roles have been identified. *Task roles* relate to behaviors associated with accomplishment of the group task,
while *relationship roles* support the socioemotional needs of and relationships between group members (Forsyth, 2014). Levi (2000) notes that task roles are often formally assigned, whereas social roles are often self-identified.

Teachers in both solo- and co-taught classrooms also fill roles. Tudor (1993) writes that there are two general categories of teacher; these categories are *teacher as knower* and *teacher as activity organizer*. *Teacher as knower* roles relate to the determination of instructional content and the pedagogical techniques and strategies used to teach that content. In *teacher as activity organizer* roles, teachers set up and steer learning activities, motivate and encourage students, and provide feedback on student performance (Tudor, 1993, p. 24). Teachers in co-teaching partnerships have been observed to enact roles that align with this classification scheme. Co-teacher as knower roles include teachers acting as instructor to groups of students or individuals, planning lessons, and developing curriculum (Bledsoe et al., 2004; Bouck, 2007). Co-teachers as activity organizers may act as classroom managers, disciplinarian to groups of students or individuals, and providers of encouragement to students (Bouck, 2007; Harbort et al., 2007; Weiss & Lloyd, 2002). Positive co-teaching outcomes have been associated with co-teachers arriving at a mutual understanding of what will be taught and what specific actions each person will carry out in support of lesson goals (Dicker, 2001; Fennick & Liddy, 2001; Kohler-Evans, 2006).

Studies have examined the roles co-teachers play in co-teaching relationships (Bledsoe et al., 2004; Bouck, 2007; Harbort et al., 2007; Walther-Thomas, 1997; Weiss & Lloyd, 2002). Little is known, however, about the roles played by members of co-teaching triads. Further, while several well-studied models of paired co-teaching exist (Cook & Friend, 1995; Embury & Kroeger, 2012; Keely, 2015), few published studies examine the possibilities present in triadic
co-teaching models. This study addresses these gaps in the co-teaching literature by investigating the roles enacted by members of science and engineering co-teaching triads composed of members with pronounced differences in pedagogical ability, classroom teaching experience, and content knowledge.

**Conceptual Framework**

Trinect co-teaching triads exemplify the construct of work teams. A work team is a group of two or more individuals working within the context of an organization to perform a collective task (Kozlowski & Bell, 2003). Members of work teams interact socially, share common goals and accountability for achieving those goals, and exhibit autonomy in terms of task performance (Banker, Field, Schroeder, & Sinha, 1995; Kozlowski & Bell, 2003; Levi, 2007). The knowledge and skill required to perform the team task is distributed among team members; team members combine resources and expertise to accomplish the team’s objectives (Mohammed & Ringseis, 2001).

Differences in team member educational and professional preparation may lead to imbalances of social power within triads. As such, this study adopts the conflict-power-status perspective of small group research (Poole et al., 2004). This approach examines groups in terms of the dynamics of power, status, resources, and social relationships, and the group structures associated with these factors, focusing on the ways in which the differences in group member influence and specialization impact group activity.

This study examined co-teaching teams. Findings from team mental models (TMM) research informed the research design and analysis of this study. TMM are the shared understandings related to aspects of the team’s collective task and work environment. TMM content includes shared representations of tasks, equipment, team member relationships, and
situations and contingencies and represents the conceptual and procedural knowledge required to accomplish team goals (Mohammed & Dumville, 2001). TMM promote team success by helping to ensure that all members of a team are “on the same page” with respect to who will be responsible for which sub-elements of the team task. The collective task of Trinect co-teaching triads was to teach elementary science and engineering lessons; sub-elements of this task may include gathering content information, asking specific questions, distributing materials, or monitoring students during hands-on activities. Shared understandings of which triad member is responsible for particular lesson sub-tasks helps to ensure that all aspects of the lesson will be implemented; in addition, triad members may be more likely to perform their own tasks efficiently to the extent they are confident that their teammates will perform theirs. Team mental models research indicates that formation of accurate shared understandings of team tasks is facilitated by collaborative planning (Stout, Cannon-Bowers, Salas, & Milanovich, 1999). With respect to Trinect co-teaching triads, during collaborative planning, team members may discuss relevant science and engineering content, decide which co-teaching model they will use, and determine who will be responsible for specific elements of the lesson.

The process of role adoption in triads may assist the assignment of lesson duties and positively contribute to the formation of a triad team mental model. Triad members may take on roles both formally and informally; as such, it is speculated that triad members will hold both specific and general roles within their teams. It is further speculated that roles held by triad members may be associated with their identity within their triad (i.e.; cooperating teacher, student teacher, or engineering fellow); the cooperating and student teachers may take on roles related to pedagogy and student management, whereas the engineering fellows may adopt roles related to knowledge of engineering and science content. Triad member roles may also
influence, and be influenced by, the co-teaching models used during lesson implementation; for instance, research on co-teaching has shown that overuse of a “lead and assistant” approach to paired co-teaching has implications for both teacher self-efficacy and student learning. Triad members were briefed on the five paired co-teaching models presented by Friend and Cook (1995) and encouraged to adapt these models for use with three person co-teaching teams. While little is known about the functionality of co-teaching triads, it is anticipated that similar relationships between co-teacher roles and triadic co-teaching models may exist.

Bouck (2007) described several examples of paired co-teacher roles; while similar roles may exist within Trinect co-teaching triads, roles in three-person co-teaching teams have not been studied. Therefore, the purpose of this study was to better understand the roles held by members of Trinect co-teaching triads in the context of the classroom. Roles are sets of typical behaviors exhibited by individuals in specific social contexts (Levi, 2007; Johnson & Johnson, 2003). As such, roles may be identified by observing an individual’s actions in a particular setting. Roles occur in social contexts, and role identification may thus be further informed by the perceptions of the persons with whom an individual frequently interacts. Individuals may also hold self-perceptions regarding the roles they play. This study investigated the roles held by members of Trinect co-teaching triads in two ways. First, the roles held by triad members were investigated through analysis of participant interviews; roles identified in this way represent both self-reported role perceptions and other-reported role perceptions. Second, triad member roles were identified through analysis of observations recorded during a triad collaborative planning meeting and a triad-taught science or engineering lesson. While the roles identified in these contexts may be highly specific, it is speculated that the roles identified through analysis of participant interviews may be of a more general nature. It is further anticipated that members of
each participant group (i.e., cooperating teacher, student teacher, and engineering fellow) will enact similar roles across triads. Additionally, to examine the extent to which specific co-teaching models may be related to triad member roles and role perceptions, this study investigated the co-teaching models used by triads during their co-taught lessons. The research questions guiding this study are: (1) What roles do members of co-teaching triads composed of a grades 3-5 classroom teacher, a student teacher, and an engineering graduate student play in their teams?; (2) What roles do Trinect triad members play during the co-planning phase of co-teaching?; (3) What roles do Trinect triad members play during the lesson implementation phase of co-teaching?; (4) What co-teaching models did Trinect triads use during their co-taught lessons?

**Study Context and Participants**

This study reports findings from a 16-week engineering professional development program in a large urban school district. Engineering graduate students from a large Midwestern university were placed with a cooperating/student teacher dyad working in grades 3-5 classrooms to form co-teaching triads; student teachers attended the same university as the engineering graduate students. Ten co-teaching triads were formed each semester, with triad assignments based on the results of a professional and personal compatibility assessment administered by Target Training International (Target Training International, 2014). The engineering fellows spent one full school day per week working with the cooperating/student teacher pair and assisted in planning and implementation of the district’s science curriculum. Engineering fellows participated for a full academic year (two 16-week placements), while the student and cooperating teachers participated for only one 16-week placement; thus, new triads were formed
each semester. Data for this study was collected during the Fall 2017 semester, which occurred during the first semester of the third year of project implementation.

**School District**

This study was undertaken in a large urban school district serving a highly diverse student population. The school district science curriculum coordinator served as the liaison between the district and the university. Co-teaching triads taught in 6 elementary schools, with 3 of these schools hosting multiple triads. The district had recently adopted NGSS, with the concomitant expectation that engineering be integrated into school science programs.

**Participants**

The engineering graduate students and student teachers were recruited from a large Midwestern university. Student teachers were all seniors in the final semester of an elementary education undergraduate program. Student teachers were made aware of the program through informational meetings held by project personnel and applied for participation the semester preceding their student teaching semester; no special experience with engineering or science was required. Acceptance decisions were made by project administrative personnel and were based on interest and demonstrated professionalism in prior school placement experiences. Engineering graduate students were required to apply for the program and have a letter of support from their major professor. They were selected based on their performance in an interview and their academic progress. Engineering fellow demographic information is reported in Table 1.

<table>
<thead>
<tr>
<th>Field</th>
<th>EF A</th>
<th>EF B</th>
<th>EF C</th>
<th>EF D</th>
<th>EF E</th>
<th>EF F</th>
<th>EF G</th>
</tr>
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<tbody>
<tr>
<td>Degree</td>
<td>PhD</td>
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<tr>
<td>Gender</td>
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<td>F</td>
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<td>M</td>
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<td>M</td>
</tr>
</tbody>
</table>

*Note. EF = Engineering fellow.*
The cooperating teachers were recruited for the project by the district’s science curriculum coordinator. They taught in grades 3-5 classrooms and represented a wide range of teaching experience and degree of comfort with teaching science and engineering. All participants received compensation for their participation.

Of the ten triads in the Fall 2017 semester, two triads did not hold their scheduled planning meeting due to the absence of a group member. As the design of the study required observation of both collaborative planning and lesson implementation, these triads were excluded from analysis. Additionally, one triad encountered challenges related to the classroom environment and had members reassigned to another school; this triad was also excluded from analysis. Thus, participants for this study included 21 individuals from 7 intact triads. Synopses of the triads’ relational characteristics are listed in Appendix 1. The Institutional Review Board (IRB) exempt approval memo is contained in Appendix 2.

**Professional Development**

Participants attended professional development workshops conducted by the project leadership, which included university faculty in science education, mathematics education, and engineering. The workshops had several goals: First, enhance participants’ understanding of effective elementary science and engineering instruction. Second, enhance participants’ understanding of the nature of engineering and the nature of science, including similarities and differences across these two disciplines. Third, help participants understand their roles in the triad and co-teaching models they could use throughout the semester in their work together. Fourth, help participants learn about the strengths each person brings to the team and get to know one another. Finally, participate in planning activities with the support of project staff and other triads.
The first workshop occurred 3 weeks prior to the start of the semester, and included three days for the engineering fellows only, with the purpose of addressing legal issues of working in schools and to prepare them for their work with teachers and young students. This was followed by two days where all triad members were present. During this time, triads received instruction and participated in activities related to NGSS-aligned elementary engineering and science education, triad roles and responsibilities, and long-range unit planning; time was also allotted for team-building experiences and a tour of the engineering fellows’ research facilities.

A day-long professional development workshop was held for the cooperating and student teachers near the midpoint of the semester. This workshop focused on improving engineering and science concept development practices through design of unit level and lesson level content sequencing and included opportunities for participants to apply these ideas in an engineering context.

The engineering fellows received additional support throughout the semester. Fellows participated in an hour-long seminar led by science education and engineering faculty. These sessions provided the opportunity for fellows to share with each other classroom successes and challenges and also served as a medium for ongoing professional development through discussion of engineering and science pedagogical practices.

**Methodology**

This study employed a case study approach to determine the roles played by members of Trinect co-teaching triads as they worked collaboratively to plan and teach engineering and science lessons. A case study is an empirical inquiry that examines a phenomenon within its real-life context in situations when the boundaries between the phenomenon and the context are not clearly evident (Yin, 2003, p. 13). In this instance, the phenomena under investigation,
which were the roles played by members of Trinect co-teaching triads, are inextricable from the context of the study – a co-teaching experience in an elementary classroom. *Roles* are the behaviors typical of people in particular social contexts and describe what individuals are expected to do and how they relate to each other (Levi, 2007; Johnson & Johnson, 2003). As such, the roles played by triad members depend to a great extent on the people with whom they work and the context in which their work is performed. Triad member roles may be different if teams were composed differently or if their placement classrooms were different, and are thus highly contextualized and amenable to a case study approach. Case study inquiry employs analysis of multiple sources of information to produce a detailed description of the case, the phenomena, and the setting (Creswell, 2013). In this study, co-teaching triads were the unit of analysis, with the sources of data being observations of collaborative planning meetings and co-taught lessons and participant interviews. Triad member roles were examined both within and across units of analysis. Data was first analyzed to determine the roles taken on by individuals within triads. Subsequently, member roles were considered across triads to create a picture of commonality of roles between participant groups. Figures 1 and 2 below depict the relationship between levels of role analysis.

![Diagram of Triad Roles](image)

**Figure 1.** Within-group team member roles.
Data Collection

Data for this study was collected during the first semester of the Fall 2017 academic year (August through December) from the seven eligible triads. To better understand co-teaching triads, data was collected in the school context and interpreted to determine the roles of individuals within their triads and also the across-team roles of each participant group. Specifically, data was collected during observations of collaborative planning meetings and co-taught lessons and participant interviews. Data was gathered by project research and administrative personnel.

Observation of triad planning meetings. For each triad, one planning meeting was observed. Observations of planning meetings were coordinated through each triad’s cooperating teacher; meetings took place during teachers’ contract hours, either before or after school, during scheduled teacher planning time, or during lunch. Field notes were taken during each planning meeting; following the observation, field notes were expanded into a narrative report. During the observations, the researcher focused on the flow of ideas between triad members, the actions performed by each person, and individual contributions of content and pedagogical content knowledge. Further, the researchers recorded their perceptions of the general nature of triad members’ interactions (e.g., collegial, tense, or domineering).

Observation of co-taught lessons. For each triad, one co-taught lesson was observed. In order to optimize observation of fidelity of member roles between lesson planning and implementation, the researcher requested that the observed lesson be the one that was most close
in time to the planning meeting; in all but one case, the observed lesson directly followed the planning meeting. During lesson observations, the researcher focused on instructional activities, evidence of collaboration, and the interactions between triad members and between triad members and students; also noted were the co-teaching models each triad used, the number of statements each triad member made to the class, and the amount of time each participant spent as lead teacher or team teacher. Human subjects approval did not allow the use of video recording, so the researcher recorded observations in field notes, which were subsequently transcribed and written into a narrative report.

**Participant interviews.** All triad members participated in semi-structured interviews (Creswell, 2013) designed to capture attitudes, reflections, and perceptions related to perceived triad successes and challenges, the functioning of the triad as a team, conceptualizations of engineering and science, and student learning of engineering and science. Interview questions were created by project research personnel and were reviewed prior to implementation. Interviews took place during the final three weeks of the semester and were performed by project research and administrative personnel. Each interview and its accompanying field notes were recorded with a LiveScribe pen. Audio files of the interviews were transcribed verbatim by an external transcription service. All three members of each triad participated in an interview, and thus 21 interviews comprise this data set.

**Data Analysis**

To determine participant roles, each data source was analyzed separately; results of these separate analyses were then combined to answer each research question.

**Observation of triad planning meetings.** Field notes taken during the observations were open coded (Strauss & Corbin, 1998) to identify the general nature of participants’ actions and
Open coding produced a set of action codes related to the observed actions and statements; example action and statement codes include “Shares idea”, “Retrieves materials”, and “Off-topic statement”. Action and statement codes created during open coding were entered into a spreadsheet containing the coded identities of each participant. A ‘1’ or ‘0’ was entered for each individual indicating whether that individual performed a coded action or made a coded statement; a ‘1’ indicated an individual was observed to engage in a particular activity, while a ‘0’ indicated they were not. Row sums gave the number of total coded actions and statements performed by each triad member; column sums provided the relative number of coded actions and statements activities made by participant groups. Action and statement code sums were then considered in coordination with the lived experience of the researcher as a presence in the collaborative planning meeting to identify the roles taken on by triad members during the planning meeting.

**Observations of co-taught lessons.** Field notes from the observations were expanded into a timeline. Timelines were first read through to gain an understanding of the general flow of the lesson. Researchers then engaged in open coding (Strauss & Corbin, 1998) to understand the instructional activities of each triad member. Open coding produced a set of action codes related to the observed instructional activities. Example action codes include “Gave Instructions”, “Asked recall question”, and “Responded to student”. Action codes created during open coding were entered into a spreadsheet containing the coded identities of each participant; a ‘1’ or ‘0’ was entered for each individual indicating whether that individual performed a coded lesson activity; a ‘1’ indicated an individual was observed to perform a particular activity, while a ‘0’ indicated they were not. Row sums gave the number of total instructional actions performed by each triad member; column sums provided the relative number of specific instructional activities
performed by each participant group. Action code sums were then considered in comparison with the amounts of time each triad member acted as lead teacher, team teacher, or assistant to identify the roles taken on by each member of the team.

**Participant interviews.** Participant interviews were analyzed for themes related to triad members’ role perceptions and were also used to support and explain participant actions observed in the lesson and planning meetings. The researcher first read through transcripts to form a general sense of the content and affect of each interview. Interview transcripts were then open coded (Strauss & Corbin, 1998) to identify statements related to participant roles. Example codes include “Identify science misconceptions”, “Classroom management experience” and “Difficulties with STEM content”. Codes developed during this phase of analysis were subsequently condensed into triad member roles based on similarity of code characteristics. Interview transcripts were then re-read from the perspective of the established role codes to examine fidelity between codes and member statements; codes were adjusted as necessary during this phase of data analysis.

**Results**

**Research Question 1: What roles do members of co-teaching triads composed of a grade 3-5 classroom teacher, a student teacher, and an engineering graduate student perceive that they play in their teams?**

**Perceived Individual Roles**

The perceived roles played by members of Trinect co-teaching triads during their co-taught lessons were (1) Experienced Teacher; (2) Steward of Developmental Appropriateness; (3) STEM Content Resource; (4) STEM Curriculum Developer; (5) Novice Teacher; and (6) Bringer of New Ideas. Participant roles exhibited the *teacher as knower* and *teacher as activity*
organizer categorization scheme proposed by Tudor (1993). “Teacher as knower” roles were Experienced Mentor, STEM Content Resource, STEM Curriculum Developer, Steward of Developmental Appropriateness, and Bringer of New Ideas. “Teacher as activity organizer” roles were Experienced Teacher and Novice Teacher. Table 2 lists the roles of members of Trinect co-teaching triads. All of the observed roles were task-related roles; no relationship roles were observed.

**Experienced Teacher.** The role of Experienced Teacher was occupied by all seven of the cooperating teachers and three of the student teachers; no engineering fellows were identified as enacting this role. Experienced Teachers enacted this role within their triads by bringing to their teams knowledge of student capabilities and ability levels, pedagogical experience, and classroom management skills. Cooperating Teacher A saw as an essential part of her role within her triad her use of pedagogical skill to work efficiently within the confines of the school schedule to meet learning goals.

> I think my expertise was knowing that we have a half an hour, what is the absolute essential thing that they have to know at the end of the half an hour? And how are we going to get there? (CT A, Interview, Line 207)

Cooperating Teacher E brought pedagogical and classroom management experience to her triad.

> Probably just what it is to teach a group people, regardless of their age, what it’s like to manage that with what that classroom management would look like. How to set up groups. How to organize students for learning. Just that kind of process. (CT E, Interview, Line 218)

Cooperating Teacher B expressed a similar sentiment: “I think my big role here was just managing the kids, being the main manager of the kids” (CT B, Interview, Line 250).
Table 2. Perceived individual roles.

<table>
<thead>
<tr>
<th>Role</th>
<th>Role Actions</th>
<th>Exemplary Statement</th>
<th>Participant Groups (N)</th>
</tr>
</thead>
</table>
| Experienced Teacher           | Instruct students; manage student behavior and logistics; provide knowledge  | “But obviously, inside the classroom the teacher did a lot of the classroom management and things like that too. And, you know, when things were going off the rails a little bit, she did a really nice job of keeping our train from wrecking.” (ENG C) | Cooperating Teachers (7)  
Engineering Fellows (0)  
Student Teachers (3)  
Total: 10 |
|                               | of district science standards                                                |                                                                                                                                                                                                                      |                                                                                        |
| Steward of Developmental      | Leverage knowledge of student abilities to ensure lesson content and         | “I know how to relate to kids and I know what's appropriate for kids at this age…” (ST E)                                                                                                                              | Cooperating Teachers (4)  
Engineering Fellows (0)  
Student Teachers (2)  
Total: 6 |
| Appropriateness               | activities are within student capabilities                                |                                                                                                                                                                                                                      |                                                                                        |
| STEM Content Resource         | Provide content knowledge input for lessons; expand and/or build upon       | “I really feel like I played the part of bringing in content.” (ENG A)                                                                                                                                                 | Cooperating Teachers (1)  
Engineering Fellows (6)  
Student Teachers (0)  
Total: 7 |
|                               | existing content; clarified content for other team members                  |                                                                                                                                                                                                                      |                                                                                        |
| STEM Curriculum Developer      | Plan science and engineering lessons; engage in long-range STEM unit        | “But science, yeah, I thought when it came to explaining content and planning out how to incorporate some engineering and some other activities, that was really my role.” (ENG D)                                              | Cooperating Teachers (0)  
Engineering Fellows (7)  
Student Teachers (4)  
Total: 11 |
|                               | planning                                                                |                                                                                                                                                                                                                      |                                                                                        |
| Novice Teacher                | Wrestle with role as new teacher; experience difficulties with              | “I really sometimes struggle with handling the class.” (ENG F)                                                                                                                                                       | Cooperating Teachers (0)  
Engineering Fellows (6)  
Student Teachers (4)  
Total: 10 |
|                               | classroom management; encounter content knowledge challenges                |                                                                                                                                                                                                                      |                                                                                        |
| Bringer of New Ideas          | Share and implement pedagogical strategies and techniques learned in         | “I think my expertise was the freshness of education. Now there's a lot of new ideas and things that are being taught.” (ST D)                                                                                           | Cooperating Teachers (0)  
Engineering Fellows (0)  
Student Teachers (5)  
Total: 10 |
|                               | university coursework (e.g. 5E model, classroom technology)                |                                                                                                                                                                                                                      |                                                                                        |
Student teachers as well saw themselves acting as Experienced Teachers. Although lacking the substantive classroom experience of their cooperating teacher partners, some student teachers expressed confidence in their teaching abilities. In this capacity, Student Teacher E expressed her ability to relate to students as being integral to her work with her triad:

I know how to teach, I know how to relate to kids and I know what's appropriate for kids at this age and I also feel like I know how to make things interesting to the children. (ST E, Interview, Line 272)

Student Teacher B summed up her role as Experienced Teacher succinctly: “I love being a teacher, I'm so dedicated I just do everything” (ST B, Interview, Line 234).

Experienced Teachers also brought to their triads a knowledge of district science standards and science curriculum materials. The district had chosen as their science curriculum the Full Option Science System (FOSS). One cooperating teacher expressed her facility with the FOSS curriculum: “… because we work with FOSS kits, so I've worked with those for several years now. So I definitely had the ability to understand how the FOSS kits work” (CT D, Interview, Line 229). Another cooperating teacher expressed similar views: “This semester, at least I had an idea of what the district was expecting. So that helps immensely, knowing that we have standards that we have to teach to and that we had brand new FOSS kits” (CT F, Interview, Line 80).

Co-teaching requires a combination of individual effort, knowledge, and skill (Cook and Friend, 1995). Utilization of individual areas of specialization is particularly important in the Trinect co-teaching model, in which two members are novice teachers. In their role of Experienced Teachers, cooperating and student teachers provide the team with a foundational set of pedagogical skills while maintaining a readiness to assist with classroom management duties as needed.
Steward of Developmental Appropriateness. Engineering graduate students possess a high-level understanding of science and engineering content; often, however, they do not have prior experience teaching in elementary schools, and thus may not have the knowledge of elementary student capabilities necessary to engage them at a level that is developmentally appropriate. Cooperating and student teachers thus played the role of Steward of Developmental Appropriateness, filtering and modifying the content and lesson ideas presented by the engineers to ensure they matched the developmental capabilities of their students. Four of the cooperating teachers and two of the student teachers were identified as acting in this capacity. One cooperating teacher made clear her role as Steward of Developmental Appropriateness, stating “I think that was my role, to really be the filter of, ‘Is this hard or not hard enough?’” (CT B, Interview, Line 254). Similar views were expressed by a student teacher, who described one of her roles within her triad as “…helping with the curriculum and trying to focus on this is what I know the students can do. And this is going to be too challenging or … knowing my students” (ST F, Interview, Line 123). Another cooperating teacher stated that her engineering fellow had high expectations of what their students could accomplish, but

where higher expectations are great, they have to be realistic. They have to be appropriate for the age group. So what I would bring is if someone in the group suggested [something] that I knew was not going to work, I could say, ‘That’s not going to work. This is why. They’re eight. Maybe we could try this.’ So just making sure that everything that we were doing was grade level appropriate. (CT E, Interview, Line 230)

Stewards of Developmental Appropriateness noted that the process of adapting to student ability levels was not always easy. A cooperating teacher stated, “…so it’s more of his [the engineering fellow’s] intelligence level is here and the kids are down here. So it’s just bringing him down to their level, and that was very difficult to do at first” (CT G, Interview, Line 369).
STEM Content Resource. Individuals who assumed the role of STEM Content Resource brought engineering and science content knowledge to their triads, expanded upon existing engineering and science curriculum materials, and probed their students and teammates for misconception views. Six of the seven engineering fellows were identified as holding the role of STEM Content Resource, along with one of the cooperating teachers (Cooperating Teacher G). Notably, none of the student teachers were identified in this role, and in some instances student teachers expressed an initial discomfort with engineering and science education (Student Teachers D and E); thus, the role of STEM Content Resource was highly important in triads.

The engineering fellows identified as STEM Content Resources describe using their content expertise to assist their teammates with content issues. Engineering Fellow A stated that her cooperating teacher frequently asked her questions before lessons to ensure that she would teach content correctly. Engineering Fellow D described using her knowledge of engineering and science content to help bolster triad lessons, and these contributions were noted by both of her teammates. Student Teacher D stated that her engineering fellow “taught us things that we had no idea about, and helped us to teach them [students] all those things” (ST D, Interview, Line 216), while Cooperating Teacher D noted that her engineering fellow “did a good job bringing in things that had to do with what we were talking about” (CT D, Interview, Line 245). Cooperating Teacher F also saw both herself and Student Teacher F playing the role of STEM Content Resource, stating that she felt they did not need to rely upon her engineering fellow for content assistance: “[Student Teacher F] and I have a strong science background, so we didn’t need him to explain the science” (CT F, Interview, Line 511). For his part, Engineering Fellow F
felt strongly about his role as STEM Content Resource, and the expressed confidence of his teammates may have left him feeling slighted:

I did see that there were points at which she [Student Teacher F] could have, I don't know, talked to me beforehand [about STEM content questions] so I had to really put in effort of “send me an email if you have any questions about that”, or “I will come talk about it. So if you have any questions ask me though”, but that never happened. (EF F, Interview, Line 324).

In addition to bringing content knowledge to his triad, Engineering Fellow B took as part of his role as STEM Content Resource the identification of misconception views: “I tried to have them sort of come up with these misconceptions and how to address these. I tried to really focus on that. That was one of my sort of main jobs” (EF B, Interview, Line 531). In spite of Engineering Fellow B’s focus on misconception views, one did slip by: Engineering Fellow B himself was observed in class presenting a misconception regarding plant growth. Thus, while engineering fellows may possess a high-level understanding of engineering and science, their fields of expertise are often quite narrow, and some foundational concepts may have been forgotten. One engineering fellow sums up this sentiment:

I had some misconceptions about outer space. I haven't talked about outer space in so long. And we talked about that for so long this semester. Yeah, a lot of these things, I had to go watch YouTube videos about it, to get caught up. Then I was like, oh yeah, that's right! (EF C, Interview, Line 315)

Engineering Fellow C also described expanding upon grade-level science content in order to prepare students for future science learning: “Yes, this is the fifth-grade definition [of gravity], but let's think about what the real definition is, and see if we can't set them up a little better for that later down the road” (EF C, Interview, Line 306).

**STEM Curriculum Developer.** Related to the notion of STEM Content Resource was the role of STEM Curriculum Developer. All seven engineering fellows were identified as STEM Curriculum Developers. While the student teachers did not typically play the role of
STEM Content Resource, four were identified as STEM Curriculum Developers (Student Teachers B, E, F, and G). STEM Curriculum Developers engaged in both day-to-day lesson planning for their triads as well as assisting with long range unit planning. Engineering Fellow A felt strongly about her role as STEM Curriculum Developer. Stating that she did “most of” the engineering and science planning for her triad, this engineering fellow felt that her role was to provide content input and plan lessons, leaving the task of lesson implementation to her teammates: “I didn't do a lot of teaching, which I think was actually good, because then I knew that my teachers actually understood the content” (EF A, Interview, Line 6). Engineering Fellow D stated that an aspect of her work involved “planning out how to incorporate some engineering activities” (EF D, Interview, Line 297). Engineering Fellow G used his knowledge of engineering and science to help interpret district standards and plan lessons accordingly: “So finding the actual lesson learned that relates to that scale and then where that's buried in that activity is probably what I tried to do mostly when it comes to science” (EF G, Interview, Line 228). Engineering Fellow G’s student teacher teammate similarly considered herself a STEM Curriculum Developer, stating that she considered part of her work within her triad to be “planning, planning, planning [engineering and science lessons]… creating a new curriculum for them to use for years on out” (ST G, Interview, Line 172). Although she expressed feelings of discomfort with engineering and science education, Student Teacher E took on the role of STEM Curriculum Developer for her triad, considering that to be an aspect of her work as a student teacher. Thus, STEM Curriculum Developers played an active, and sometimes territorial, role in planning lessons for their triads.

**Novice Teacher.** The composition of Trinect co-teaching triads was such that two of the three members were relatively new to elementary education. Not surprisingly, then, a frequently
identified role within triads was that of Novice Teacher; six engineering fellows and four student teachers were identified as Novice Teachers. Novice Teachers described themselves as wrestling with student behavior and ability levels, occasionally turning to their cooperating teachers for assistance. Having little experience teaching elementary students, the engineering fellows faced particular challenges related to classroom management. Engineering Fellow G, for instance, stated “I really sometimes struggle with handling the class”, and when students were “going through one of their moods” he would “really fall back on the [cooperating] teacher” for assistance (EF G, Interview, Line 314). Engineering Fellow D faced similar challenges, noting the outsize influence of a small number of disruptive students: “there were days when there would be one or two kids [disrupting the class] and then it would ruin part of the day” (EF D, Interview, Line 47). In these instances, Cooperating Teacher D would step into her role as Experienced Teacher to provide classroom management assistance. Engineering Fellow B appeared surprised when encountering elementary student ability levels for the first time, noting that an improperly phrased question “could throw [some] students off, and they won’t go back on track, at least for that day” (EF B, Interview, Line 37). Student teachers also encountered challenges in their role as Novice Teacher; Student Teachers D and E both described feeling overwhelmed with the responsibilities of running an elementary school classroom.

**Bringer of New Ideas.** Student teachers are in their final semester of elementary education degree and licensure programs; accordingly, they are well-versed in the fundamentals of elementary pedagogy and may bring with them to their triads fresh perspectives on teaching and learning. Student Teacher D exemplifies the role of Bringer of New Ideas, stating

I think my expertise was the freshness of education. Now there's a lot of new ideas and things that are being taught. When you go to college to become a teacher there's a lot of new things and new ideas, so I think I brought that to the table. (ST D, Interview, Line 212)
An important aspect of student teachers’ “freshness of education” was the integration of educational technology. Student Teacher B stated

I made a lot of videos and a lot of interactive stuff for the kids to do, and they liked that. And I also was a TA for the Toying with Technology [course at the university] so I brought a lot of ideas from there. (ST B, Interview, Line 22)

Cooperating teachers noticed and appreciated these new ideas and perspectives. Cooperating Teacher E enthusiastically praised her student teacher partner:

My student teacher is fantastic. She's brought a lot of really fresh, wonderful, creative new ideas to my room. I've been teaching for a while, and didn't realize how much more I could have been doing because you kind of get into a rut of what you've always done. But she's brought so many amazing things to my room, so I've learned a ton from her. (CT E, Interview, Line 9)

While student teachers did not always speak as confidently about their roles within their triads as their teammates, they nevertheless had important contributions to make as exemplified by the role of Bringer of New Ideas. New ideas and perspectives can serve as a catalyst for re-energized teaching practices and novel applications of technology.

**Perceived Individual Roles Within and Across Triads**

Once the data were analyzed to understand the roles assumed within the teams, analysis focused on who assumed these roles within and across the triads. Individuals played multiple roles within their triads, and some roles were played by multiple team members. Considered together, these roles portray the range of individual knowledge and experience present in co-teaching triads. Triad members brought to their teams knowledge of pedagogy and classroom management, science and engineering content support, and new perspectives on teaching and learning. Member specialization was spread across triads, and while individuals did play multiple roles, the distribution of intra-triad roles supports the notion that as a pedagogical approach, co-teaching represents an amalgamation of individual knowledge, skill, and
experience. Role enactment was dense within triads. All six roles were identified in both Triads A and B, four triads (Triads C, D, E, and F) had one role unfilled, and one (Triad G) had two unfilled roles. Table 3 displays the roles of triad members as individuals within triads.

Table 3. Perceived individual roles within triads.

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Exp. Teacher</th>
<th>Steward of Developmental Appropriateness</th>
<th>STEM Content Resource</th>
<th>STEM Curriculum Developer</th>
<th>Novice Teacher</th>
<th>Bringer of New Ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triad A</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ENG</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Triad B</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENG</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triad C</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENG</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triad D</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENG</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triad E</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENG</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triad F</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENG</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triad G</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

A correspondence between triad member area of specialization and role was observed. The cooperating teachers were more likely to take on roles related to pedagogical experience (Experienced Teacher and Steward of Developmental Appropriateness); student teachers as well took on these roles, and also enacted roles related to their status as pre-service teachers (Novice Teacher and Bringer of New Ideas). All of the engineering fellows held roles pertaining to the use of science and engineering content knowledge (STEM Content Resource and STEM Curriculum Developer). Table 4 displays triad member roles across triads.
Table 4. Perceived individual roles across triads.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Exp. Teacher</th>
<th>Steward of Developmental Appropriateness</th>
<th>STEM Content Resource</th>
<th>STEM Curriculum Developer</th>
<th>Novice Teacher</th>
<th>Bringer of New Ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT A</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT B</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT C</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT D</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT E</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT F</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>CT G</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG A</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ENG B</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG C</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG D</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG E</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG F</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG G</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ST B</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ST E</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ST F</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ST G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Research Question 2: What roles do Trinect triad members play during the co-planning phase of co-teaching?

Researchers coordinated with triads to visit the planning meetings directly preceding the co-taught lessons. Of the seven triads observed in this study, five held the lessons on the same day as the planning meeting, one triad met to plan the lesson on a Friday and taught it the following Tuesday, and one did not hold a planning meeting during their scheduled observation. Three triads devoted the entirety of the planning meeting to preparing for their observed co-taught lessons, while three others did not; Triad F was not observed to plan for the observed lesson at all. When not directly engaged in planning for the co-taught lesson, triads engaged in planning for other subjects. Table 5 displays information related the temporal aspects of the observed planning meetings. Triad G did not hold a planning meeting and thus is not included in this table.
Table 5. Temporal aspects of triad planning meetings.

<table>
<thead>
<tr>
<th>Triad</th>
<th>Length of Planning Meeting</th>
<th>Time Spent Planning for Observed Lesson (minutes) (fraction)</th>
<th>Planning Meeting &amp; Lesson on Same/Different Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>47</td>
<td>15 (0.32)</td>
<td>Same</td>
</tr>
<tr>
<td>B</td>
<td>45</td>
<td>45 (1.0)</td>
<td>Different</td>
</tr>
<tr>
<td>C</td>
<td>35</td>
<td>10 (0.29)</td>
<td>Same</td>
</tr>
<tr>
<td>D</td>
<td>30</td>
<td>30 (1.0)</td>
<td>Same</td>
</tr>
<tr>
<td>E</td>
<td>18</td>
<td>18 (1.0)</td>
<td>Same</td>
</tr>
<tr>
<td>F</td>
<td>40</td>
<td>0 (0)</td>
<td>Same</td>
</tr>
</tbody>
</table>

Observations of collaborative planning meetings were coded for the nature and frequency of participant statements and actions that occurred during the meeting. During the planning meetings, triad members planned and discussed their observed lessons, engaged in long-range unit planning, gathered materials needed for lesson activities, and talked and joked amongst themselves. Table 6 lists the statement and action codes along with the number of observed occurrences of each both in total and by participant groups.

Table 6. Planning meeting statement and action codes occurrences in total and by group.

<table>
<thead>
<tr>
<th>Code</th>
<th>Total Occurrences</th>
<th>N(CT)</th>
<th>N(ENG)</th>
<th>N(ST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shares Idea</td>
<td>67</td>
<td>24</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>Lesson Statement</td>
<td>55</td>
<td>26</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Lesson Question</td>
<td>43</td>
<td>20</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Shares Content</td>
<td>26</td>
<td>8</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Retrieves Material</td>
<td>18</td>
<td>7</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Off-topic Statement</td>
<td>16</td>
<td>6</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Content Question</td>
<td>15</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Off-topic Action</td>
<td>11</td>
<td>2</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Responds to Question</td>
<td>10</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Demonstrates</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Role Declaration</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Leaves Room</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Retrieves Information</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>283</td>
<td>111</td>
<td>86</td>
<td>86</td>
</tr>
</tbody>
</table>

Table 7 displays the planning meeting statement and action codes by the number of individuals within each participant group whose actions exemplified that code. Although Triad G had a scheduled group planning meeting, the meeting did not occur. Thus, six individuals individuals comprise each participant group.
Table 7. Statements and actions by individuals in participant groups.

<table>
<thead>
<tr>
<th>Code</th>
<th>N(CT)</th>
<th>N(ENG)</th>
<th>N(ST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shares Idea</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Lesson Statement</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Lesson Question</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Shares Content</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Retrieves Material</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Off-topic Statement</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Content Question</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Off-topic Action</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Responds to Question</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Demonstrates</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Role Declaration</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Leaves Room</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Retrieves Information</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

While the engineering fellows were unanimously identified in the participant interviews as holding the roles of STEM Content Resources, the degree to which they enacted this role during planning more extensively than their teammates appears limited. Of the 26 observed instances of Shares Content reported in Table 7, 8 such statements were made by cooperating teachers, 12 were made by engineering fellows, and 6 were made by student teachers. These statements were made by 3 student teachers, 4 engineering fellows, and 3 cooperating teachers. Thus, while engineering fellows expressed in their interviews that they had a role that was classified as a STEM Content Resources, during the observed planning meetings they did not make content contributions in substantial excess of their teammates.

Planning meeting statement and action codes were summed for each participant. Participant planning meeting roles were identified based on the combined number of actions and statements for each participant in coordination with the lived experience of the researcher as a presence at the planning meeting. These roles were Full Collaborator, Supporting Collaborator, and Observer. Table 8 lists the planning meeting codes and their frequency of occurrence in total and by participant groups. Triad G did not hold a planning meeting during their scheduled observation and thus for that team no roles were identified.
Table 8. Planning meeting roles and frequency counts.

<table>
<thead>
<tr>
<th>Role</th>
<th>Role Actions</th>
<th>Participant Groups (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Collaborator</td>
<td>Make significant contributions to team planning meetings in terms of lesson ideas and statements; asks and responds to questions; remain attentive and engaged throughout duration of planning meeting</td>
<td>Cooperating Teachers (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Fellows (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student Teachers (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total: 14</td>
</tr>
<tr>
<td>Supporting Collaborator</td>
<td>Limited contribution to planning meeting; remains attentive throughout meeting</td>
<td>Cooperating Teachers (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Fellows (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student Teachers (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total: 1</td>
</tr>
<tr>
<td>Observer</td>
<td>Little to no contribution to planning meeting; may remain silent throughout meeting; disengaged from meeting or working off-task</td>
<td>Cooperating Teachers (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Fellows (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student Teachers (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total: 3</td>
</tr>
</tbody>
</table>

**Full Collaborator.** Full Collaborators were identified by the sustained and substantive contributions they made during the observed planning meetings. Individuals identified as Full Collaborators shared with their teammates numerous ideas related to the observed lesson and long-range planning. Cooperating Teacher C and Student Teacher C, for example, shared between them ideas regarding how they might best structure their upcoming Properties of Air lesson, while Cooperating Teacher E shared with her teammates her thoughts on how best to sequence elements of their Structures of Life engineering activity. Full Collaborators further shared and discussed content. Cooperating Teacher B and Engineering Fellow B were on several occasions observed to discuss content related to plant life cycles, and they both shared content information with Student Teacher B. Full Collaborators also gathered materials and readied
them for use in class, and asked and responded to questions. While Full Collaborators did engage in off-topic actions and discussions, they did not substantially hinder the general flow of the meeting.

Cooperating Teacher F and Engineering Fellow F represent an interesting case of Full Collaborators. Initially, Triad F had arranged to hold their planning meeting early in the morning, before the start of the school day. When the observer arrived at the school, he was informed that Engineering Fellow F had slept through his alarm and that the triad would not begin planning until he arrived; Engineering Fellow F did not arrive at the school with enough time to plan before students arrived. The observer returned to the site approximately two hours later for a rescheduled planning meeting. During this second planning meeting, Cooperating Teacher A met with a fellow grade-level teacher to engage in long-range planning for a literacy unit; of the approximately 45 minutes the observer was present, 25 minutes were dedicated to literacy planning; during the remaining 20 minutes, Cooperating Teacher F and Engineering Fellow F worked on creating engineering themed math problems and did not discuss the upcoming engineering lesson.

**Supporting Collaborator.** Individuals identified as Supporting Collaborators engaged in the planning meetings on a limited basis. Supporting Collaborators shared ideas, asked questions, and made statements relevant to the planning task, but did so sporadically. However, while the direct participation of Supporting Collaborators was limited in extent and duration, they appeared engaged and attentive throughout the meeting. During Triad E’s planning meeting related to a Cycles of Life lesson that featured crayfish, Engineering Fellow shared lesson ideas and a crayfish video. In each case, however, his ideas were rejected by Student Teacher E; after several such rejections, Engineering Fellow E sat silently, and while he was clearly attentive to
the flow of conversation between his teammates and frequently made statements indicating acknowledgement of statements made by his teammates, he did not make any further contribution. Thus, while Engineering Fellow E may have approached the Planning Meeting as a Full Collaborator, interactions with Student Teacher E appeared to limit the extent to which he wished to engage with his teammates.

Observer. Observers made little to no contribution to the triad planning meeting. At the beginning of his team’s planning meeting, Student Teacher A, for instance, demonstrated for his teammates how he thought their students might use provided materials (pipe cleaners, craft pompoms, etc.) to build a “hand pollinator” and raised the possibility of adding “extra criteria” to the their upcoming engineering lesson; these actions occurred during the first 3 minutes of the meeting, after which he made no further contributions. Engineering Fellow C made contributions to her triad’s planning meeting in excess of those made by Engineering Fellow E; however, when she did speak, it was at the prompting of Student Teacher C, who appeared to be making substantive effort to keep Engineering Fellow E engaged with the work her triad was doing. The situation in this triad thus appears to be the reverse of what was observed in Triad E. Engineering Fellow E appeared motivated to contribute, but his participation was limited by Student Teacher E; in Triad C, Engineering Fellow C did not initially appear engaged, but her participation was actively solicited by Student Teacher C. Observers may also have been disengaged from the planning meeting. Student Teacher F was observed grading student papers for the entirety of Triad F’s planning meeting, and did engage with her teammates at all.

Fourteen participants were identified as Full Collaborators during the planning meetings, one participant was identified as a Supporting Collaborator, and three participants were identified as an Observer. Table 9 displays planning meeting roles by individuals within their
Of the six triads observed during planning, two triads (Triad B and Triad D) had all three members engaged as Full Collaborators, while the remaining four triads (Triads A, C, E, and F) had two Full Collaborators.

Table 9. Planning meeting roles by participant.

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Full Collaborator</th>
<th>Supporting Collaborator</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triad A</td>
<td>CT x</td>
<td>ENG x</td>
<td>ST x</td>
</tr>
<tr>
<td>Triad B</td>
<td>CT x</td>
<td>ENG x</td>
<td>ST x</td>
</tr>
<tr>
<td>Triad C</td>
<td>CT x</td>
<td>ENG x</td>
<td>ST x</td>
</tr>
<tr>
<td>Triad D</td>
<td>CT x</td>
<td>ENG x</td>
<td>ST x</td>
</tr>
<tr>
<td>Triad E</td>
<td>CT x</td>
<td>ENG x</td>
<td>ST x</td>
</tr>
<tr>
<td>Triad F</td>
<td>CT x</td>
<td>ENG x</td>
<td>ST x</td>
</tr>
</tbody>
</table>

Table 10 displays the identified planning meeting roles by participant group. Members of Triad G did not hold a planning meeting during their scheduled observation and thus are not represented. All six of the cooperating teachers observed in a planning meeting were identified as Full Collaborators, as were three of the engineering fellows and five of the student teachers. Three of the six observed engineering fellows were not identified as Full Collaborator, although Engineering Fellow E appeared to attempt to act as such but was precluded from doing so by Student Teacher E.
Table 10. Planning meeting roles by participant group.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Full Collaborator</th>
<th>Supporting Collaborator</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT A</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT B</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT C</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT D</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT E</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT F</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG A</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG B</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG C</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ENG D</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG E</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST B</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST C</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST D</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST E</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST F</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Co-teaching triads were observed during the collaborative planning phase of co-teaching. Roles were identified based on the actions and statements of triad members during a team planning meeting. No obvious association was observed between the roles of Full Collaborator, Supporting Collaborator, and Observer and team members’ identity within their triads.

**Research Question 3: What roles do Trinect triad members play during the lesson implementation phase of co-teaching?**

Observations of co-taught lessons were coded for the instructional actions performed by each triad member; seventeen co-teaching action codes were identified. Table 11 lists these codes along with the number of observed occurrences of each in total and by number of individuals performing that action.
Table 11. Co-taught lesson action code total occurrences and occurrences by participant group.

<table>
<thead>
<tr>
<th>Code</th>
<th>Total Occurrences</th>
<th>N(CT)</th>
<th>N(ENG)</th>
<th>N(ST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assists Students</td>
<td>19</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Confers with Co-teacher</td>
<td>17</td>
<td>7</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Gives Instructions</td>
<td>13</td>
<td>5</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Lead Teaches</td>
<td>12</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Distributes Materials</td>
<td>12</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Observer</td>
<td>12</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Classroom Management</td>
<td>11</td>
<td>4</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Pedagogical Strategy</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Responds to Student</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Clarifies Statement</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Lectures</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Out of Room</td>
<td>8</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Leads Discussion</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Asks Question</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Off Task</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Delivers Content</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Supports Lead Teacher</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>167</td>
<td>66</td>
<td>40</td>
<td>65</td>
</tr>
</tbody>
</table>

Examination of Table 11 supports the identification of student and cooperating teachers as holding roles related to teaching students; 66 and 65 lesson action codes were recorded for the cooperating and student teachers, respectively, while 40 were recorded for the engineering fellows. Cooperating and student teachers were observed engaging in classroom management activities, using pedagogical strategies (e.g., “think, pair, share”), and responding to students more frequently than the engineering fellows; lead teacher duties were most frequently held by student teachers. Engineering fellows were most frequently observed distributing materials and observing the lesson, activities consistent with their identification in Research Question 1 as holding roles not directly related to teaching students. While the engineering fellows were unanimously identified as playing roles related to STEM content knowledge and curriculum, during the co-taught lessons they were not observed to engage in content-related activities. This observation aligns with what was seen during the planning meetings, during which time the engineering fellows shared content with approximately the same frequency as the cooperating teachers and student teachers. The observed lessons were predominantly hands-on engineering
lessons, which provided numerous opportunities for triad members to assist individual and
groups of students and confer with teammates.

During the observed lessons, the approximate amounts of time each triad member was
observed to be acting in a lead teacher role was recorded; this information is presented in Table
12. During Triad B’s lesson, an ELL teacher and student teacher led the class in a vocabulary
exercise; this activity is represented by the column “Other”. Many of the observed lessons were
hands-on engineering and science activities, with a great deal of time devoted to student work
time; teachers were counted as a lead teacher during this time if they had clear responsibility for
directing the flow of student activity. The student teachers were approximately twice as likely to
be a lead teacher as the cooperating teachers and nearly eight times more likely to be a lead
teacher than the engineering fellows.

Table 12. Triad lesson time and member time as lead teachers.

<table>
<thead>
<tr>
<th>Triad</th>
<th>Lesson Time (minutes)</th>
<th>Cooperating Teacher (minutes)</th>
<th>Engineering Fellow (minutes)</th>
<th>Student Teacher (minutes)</th>
<th>Other (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>43</td>
<td>27</td>
<td>3</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>55</td>
<td>0</td>
<td>4</td>
<td>38</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>46</td>
<td>0</td>
<td>0</td>
<td>46</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>65</td>
<td>47</td>
<td>18</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>25</td>
<td>12</td>
<td>0</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>315</td>
<td>86</td>
<td>25</td>
<td>185</td>
<td>13</td>
</tr>
</tbody>
</table>

Members of Trinect co-teaching triads were identified as enacting three roles during the
observed co-taught lessons: (1) Lead Teacher; (2) Supporting Teacher; and (3) Classroom
Assistant. Roles were identified based on the co-taught lesson action codes, the amount of time
each member was in front of the class as a lead teacher, and the lived experience of the
researcher as a presence in the classroom. Table 13 lists the roles played by each triad member
during the observed co-taught lesson and the frequency with which members of each participant
group played each role. The most frequently identified roles were those of Lead Teacher, held
by 6 student teachers, and Classroom Assistant, as held by the all of the engineering fellows; cooperating teachers acted as both Lead and Supporting Teachers.

Table 13. Triad member roles during co-taught lessons.

<table>
<thead>
<tr>
<th>Role</th>
<th>Role Actions</th>
<th>Participant Groups (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Teacher</td>
<td>Serve as central focus of student attention for sustained duration; provide substantive content and instructions; lead discussions; perform majority of classroom management and logistics activity; respond to majority of student questions</td>
<td>Cooperating Teachers (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Fellows (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student Teachers (6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total: 9</td>
</tr>
<tr>
<td>Supporting Teacher</td>
<td>Central focus of student attention for limited time; clarify or expanded upon content or instructions provided by lead teacher; assist with classroom management and logistics on a limited basis</td>
<td>Cooperating Teachers (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Fellows (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student Teachers (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total: 6</td>
</tr>
<tr>
<td>Classroom Assistant</td>
<td>Assist with classroom logistics activity (e.g., distribute materials); engage in low-level classroom management; provide individual assistance to groups of students or individuals</td>
<td>Cooperating Teachers (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineering Fellows (7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student Teachers (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total: 10</td>
</tr>
</tbody>
</table>

**Lead Teacher.** Individuals in the Lead Teacher role served as the central focus of student attention for a sustained and substantial amount of time. Lead Teachers gave instructions, delivered content, led discussions, and were responsible for the majority of
classroom management and logistics activities. In addition, student comments and questions were directed toward the Lead Teacher. Student teachers were mostly frequently observed to play the role of lead teacher (n = 6), with only one engineering fellow acting as lead teacher (ENG D). This result aligns with the frequency with which engineering fellows were identified as playing the role of Experienced Teacher – no engineering fellows perceived that they held this role. In three of the lessons, lead teacher duties were shared between the cooperating teacher and student teacher; as these two teachers did not together serve as the central focus of students’ attention, these lessons were not considered to be team taught.

**Supporting Teacher.** Individuals playing the role of Supporting Teacher provided content and classroom management and logistics support to the Lead Teacher. Supporting Teachers served as the focus of student attention, but on a limited basis. Triad members acting as Supporting Teacher clarified or expanded upon statements and instructions provided by the lead teacher, asked questions, and assisted the Lead Teacher with classroom management and logistics. Supporting teachers did not lead class discussions, and while they did respond to student questions, they did so by means of interjection and were not the intended recipient of the question. A vignette from the lesson taught by Triad C exemplifies the nature of the Lead/Supporting Teacher relationship. Student Teacher C, acting as Lead Teacher during this lesson, had asked students to estimate the mass, in grams, of a partially inflated rubber playground ball. Student Teacher C asked students if they had ever “felt grams before”, an inquiry to which they responded affirmatively. Directly following this exchange, Cooperating Teacher C stepped in and reviewed the use of grams as a unit of mass, passing out to each table a 100 g mass intended to serve as a point of reference for making the metric estimates. Supporting Teachers also provided classroom management support. For example, while engaged in a class
discussion as Lead Teacher, Engineering Fellow D encountered serious classroom management challenges; students would not pay attention and would frequently talk over her, causing her to lose control of the class. When this occurred, Cooperating Teacher D would step in to regain students’ attention and admonish those who were disruptive. While Supporting Teachers would share students’ attention with the Lead Teacher, this bifurcation of focus was not of a sustained nature and thus not considered an example of team teaching (Cook & Friend, 1995).

**Classroom Assistant.** Individuals acting in the role of Classroom Assistant during co-taught lessons were not the focus of student attention to any extent. Classroom Assistants did not make statements or ask questions during the lesson, and were often observed to sit aside while instruction by Lead or Supporting Teachers was occurring. Although they did not engage in whole-class instruction or discussion, Classroom Assistants frequently would interact with individual students or groups of students, in which capacity they provided assistance in the form of clarification of instructions or content. Classroom Assistants provided logistical support to Lead Teachers (e.g., distributing materials upon request) and engaged in low-level classroom management activity (e.g., quieting individual disruptive students during whole-class discussion). The role of Classroom Assistant was not considered to be mutually exclusive relative to the Lead and Supporting Teacher roles; due to the collaborative nature of co-teaching, triad members could act as Lead Teacher, Supporting Teacher, and Classroom Assistant within the same lesson. However, the role of Classroom Assistant was assigned contingent on the extent to which other roles were occupied. For instance, a Lead Teacher sitting to the side while a Supporting Teacher led a discussion was not considered a Classroom Assistant. The role of Classroom Assistant was most frequently played by the engineering fellows, with all seven
acting in this capacity. Table 14 displays co-teaching roles with respect to triads and individuals within triads.

Table 14. Co-teaching roles by triad and individual.

<table>
<thead>
<tr>
<th>Triad</th>
<th>ID</th>
<th>Lead Teacher</th>
<th>Supporting Teacher</th>
<th>Classroom Assistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CT</td>
<td>ENG</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>B</td>
<td>CT</td>
<td>ENG</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>C</td>
<td>CT</td>
<td>ENG</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>D</td>
<td>CT</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ENG</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>CT</td>
<td>ENG</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>CT</td>
<td>ENG</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>CT</td>
<td>ENG</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Of interest are the actions of Supporting Teachers and Classroom Assistants when not directly engaged in role-related activities. Cooperating teachers often were observed to grade papers, confer with other teachers, or leave the room during the lesson. Cooperating teachers also used such “down time” to manage student behavior and performance issues. In two instances, cooperating teachers were observed to loudly admonish students for late or missing work; these upbraidings were of a sustained nature and though they took place outside of the room, they could be heard clearly and caused consternation among the students.

Student teachers and engineering fellows displayed a strong tendency to remain “on task”. In one instance, however, a student teacher was observed to be engaged in a text-message conversation (on both a smartphone and laptop computer) for nearly the entire duration of the
lesson. This behavior was problematic for the engineering fellow serving as Lead Teacher, as the student teacher mistimed the distribution of materials, which cost the engineering fellow control of the class and ultimately required the cooperating teacher to step in to regain students’ attention.

Table 15 displays triad member co-teaching roles by participant group. Six of the student teachers occupied the role of Lead Teacher, with four cooperating teachers acting in support of them. The Lead and Supporting Teacher roles were occupied by only a single engineering fellow each. The distribution of roles observed during the co-taught lessons aligns with the role perceptions described by triad members described in their interviews.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Lead Teacher</th>
<th>Supporting Teacher</th>
<th>Classroom Assistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT A</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>CT B</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT C</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT D</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>CT E</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT F</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>CT G</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ENG A</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>ENG B</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG C</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG D</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>ENG E</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG F</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG G</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST A</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ST B</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>ST C</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>ST D</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ST E</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>ST F</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST G</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Trinect co-teaching triads were observed during the co-implementation phase of co-teaching. Three team member roles were identified: Lead Teacher, Supporting Teacher, and Classroom Assistant. Student teachers were most likely to adopt the role of Lead Teacher, while
the Supporting Teacher role was most frequently held by a cooperating teacher. The engineering fellows generally engaged in actions indicative of a role as a classroom assistant.

**Research Question 4: What co-teaching models did Trinect triads use during their co-taught lessons?**

Research indicates that the choices made by co-teachers regarding the co-teaching models they will use have implications for co-teacher relationships and student perceptions of their co-taught classes. For this reason, researchers recorded the co-teaching models used by triads were recorded during their co-taught lessons. Within the observed lessons, triads unanimously employed a “one teach/two assist” model of co-teaching. In this model, one lead teacher delivers instruction while the others provide assistance in the form of content, management, and logistical support. In this study, lead teaching responsibilities were shared between the cooperating and student teachers. In Triad A and Triad D, lead teacher responsibilities were shared between the cooperating and student teachers and the cooperating teacher and the engineering fellow, respectively. As at no time did the lead teachers substantively share instructional duties, these lessons were considered to exemplify a “lead with assistants” approach and not team teaching.

**Discussion**

The purpose of this study was to better understand the roles played by members of co-teaching teams composed of individuals with diverse areas of individual specialization in the context of the classroom. Results of this study indicate that members of Trinect co-teaching triads held each held multiple roles within their triads, and that the manner in which the roles were distributed tended to align with individuals’ identities within their triads. In addition,
instances of role conflict were also observed. During their co-taught lessons, triads unanimously used a “lead with assistants” approach to co-teaching.

**Role Stratification**

A central rationale for co-teaching as a pedagogical strategy is the admixture of individual knowledge, skill, and experience each co-teacher brings to the partnership; by combining individual skillsets, co-teachers have the potential to create a learning environment substantively more rich than what is achievable by a single co-teacher (Cook & Friend, 1995; Murawski, 2003). Research findings from studies of co-teachers indicate that positive co-teaching experiences are facilitated when co-teacher roles and responsibilities are well-defined (Dieker, 2001; Fennick & Liddy, 2001; Kohler-Evans, 2006). Work by Bledsoe et al. (2004) studied K-12 classroom teacher–graduate STEM fellow partnerships in the context of the GK-12 program; findings indicate that participant roles were often in alignment with individual areas of expertise. Findings from the current study support the notion that members of co-teaching teams composed of members with diverse areas of knowledge, skill, and experience adopt roles related to their individual areas of specialization.

Analysis of participant interviews identified six general roles within triads; within their teams, members held the roles of Experienced Teacher, Steward of Developmental Appropriateness, STEM Content Resource, STEM Curriculum Planner, Novice Teacher, and Bringer of New Ideas. As elementary school pre- and inservice teachers often lack experience with engineering education and may encounter further challenges teaching science (Banilower et al., 2013; Davis, Pettish, & Smithy, 2006), considered together, these roles represent aspects of the knowledge and skill needed to successfully implement engineering and science lessons. Shulman (1986) discussed domains of teacher knowledge; among these domains are content
knowledge, pedagogical content knowledge, and curricular knowledge. Content knowledge is the body of subject matter knowledge possessed by a teacher, along with an understanding of the manner in which that knowledge is structured. Pedagogical content knowledge adds to the integrated factual understandings contained in content knowledge by including knowledge of how to best facilitate teaching content knowledge; aspects of pedagogical content knowledge include the models, demonstrations, and strategies that facilitate content knowledge learning, as well as an understanding of what makes particular concepts easy or difficult to learn (Shulman, 1986). Curricular knowledge represents teacher knowledge of the instructional materials and curriculum programs related to a subject area. In the instance of Trinect co-teaching triads, engineering and science content knowledge is associated with the roles of STEM Content Resource and Experienced Teacher, while the STEM Curriculum Developer and Experienced Teacher roles correspond with the pedagogical and curricular knowledge domains. Pedagogical content knowledge is represented by the roles of Experienced Teacher, Steward of Developmental Appropriateness, and, although to a more limited extent, the Novice Teacher and Bringer of New Ideas roles. Thus, the general roles identified within Trinect co-teaching triads represent important aspects of the spectrum of knowledge required to teach engineering and science lessons. Further, the differentiation of roles here identified supports the notion that in co-teaching relationships, knowledge, skill, and experience are often distributed among co-teachers. Cooperating Teacher F speaks to this notion:

This semester I think the biggest strength that we had was having all three of us to kind of look at situations and say, ‘Okay, this is what, we're coming from a teaching perspective. We're coming from an engineering perspective and as a student teacher coming from, I really don't know what I'm doing yet, but this is what, I'm willing to try anything.’ (CT F, Interview, Line 4)
Findings from research on GK-12 classroom teacher-graduate STEM fellow partnerships indicate that role distribution often aligns with individual areas of specialization (Bledose et al., 2004); results from the present study indicate that a similar stratification of roles occurred within Trinect co-teaching triads. Cooperating teachers have extensive experience with elementary school pedagogy and classroom management and knowledge of student capabilities. Not surprisingly, all seven cooperating teachers were identified as Experienced Teachers, and four were viewed as Stewards of Developmental Appropriateness. As Experienced Teachers and Stewards of Developmental Appropriateness, cooperating teachers said they used their knowledge of pedagogy and students to assist with classroom management, provide input related to pedagogical strategies, and ensure that the content and activities in triad-taught engineering and science lessons were congruent with student capabilities. Although less experienced in the classroom as their cooperating teachers, three student teachers were also perceived as holding the role of Experienced Teacher; these student teachers spoke of bringing to their triads knowledge of pedagogy and classroom management. Interestingly, Student Teacher E perceived herself as both an Experienced Teacher and a Novice Teacher. While student teachers have yet to take responsibility for their own classrooms and realize they have “room to grow”, the experience gained through university courses and fieldwork likely provides them confidence in their ability to teach and manage students.

The perception of cooperating and student teachers as holding roles related to knowledge of pedagogy and students was supported by their activities during the triad taught lessons. Six of the student teachers were clearly identifiable as Lead Teachers during their lessons. During these lessons, these student teachers extensively gave instructions, engaged in classroom management activities, used pedagogical strategies (e.g., “share your thinking with an ‘elbow
partner”), and led discussions. In some instances, these student teachers were supported by their cooperating teachers; in these cases, the cooperating teachers clarified instructions or statements made by the student teachers or encouraged students to work with an increased sense of urgency. Triads A, D, F, and G were observed teaching engineering lessons, and in these cases all triads but one (Triad D) had the student teacher acting in the Lead Teacher role. As preservice elementary teachers often infrequently encounter opportunities to teach engineering, these student teachers were served in good stead by their participation in Trinect.

Triad D represents an interesting case with respect to the role of Lead Teacher. While Cooperating Teacher E and Engineering Fellow E shared lead teacher duties throughout the lesson, Student Teacher E spent that time sitting at a table in the back of the room. From the perspective of the researcher, Student Teacher E could be clearly seen as involved in a text message exchange on a popular social media platform; this message exchange would continue for the duration of the lesson. Approximately 20 minutes into the lesson, Student Teacher E stood up to distribute the materials needed for the “hand pollinators” they were to design. However, she did so with no obvious signal from Engineering Fellow E, who was engaged in a whole-class discussion; this activity resulted in Engineering Fellow E’s loss of control of the class. In the ensuing chaos, Cooperating Teacher E was required to step in to regain students’ attention. Perhaps not surprisingly, during their planning meeting, this team had not discussed lesson logistics or who would do what during the lesson. Authentically co-taught lessons involve substantial participation of all members of the co-teaching team (Cook and Friend, 1995); co-teaching effectiveness is facilitated when roles are clearly defined (Dieker, 2001; Fennick & Liddy, 2001; Kohler-Evans, 2006). The situation resulting from Student Teacher E’s mistiming of materials distribution may likely have been avoided had the team discussed lesson
roles during planning. In addition, with one member engaged in social media messaging, this triad was not making efficient use of all of their team members, nor were they working to realize the potential benefits of having multiple instructors in one classroom.

While the cooperating and student teacher participant groups were identified in roles related to pedagogy and knowledge of students, none of the engineering fellows were observed to hold these roles. Rather, the engineering fellows were unanimously identified by both themselves and their teammates as STEM Content Resources and STEM Curriculum Developers. In this capacity, participants reported that the engineering fellows brought content knowledge to their triads, assisted in planning lessons and units, and addressed misconceptions. An extreme case of this role differentiation was represented by Engineering Fellow A, who in her interview expressed her perception that her role was primarily related to engineering and science content support and planning. Engineering Fellow A felt that her inexperience as a teacher limited her ability to effectively co-teach. Instead, she considered the primary function of her role to be lesson and unit planning; the responsibility for teaching from the curriculum she developed rested with her teammates:

I had a lot of hope that it [lessons developed by Engineering Fellow A] would be successful, because I wrote a lot of the plans. I think ultimately it was more refreshing to just see it happen and not feel responsible for teaching it. So many times, my teacher has so much better practices than me in teaching it. Honestly, I kind of even hated the idea of having to do it. (EF A, Interview, Line 28).

Engineering Fellow A expressed a clear distaste for teaching. Her sentiments here were supported by her actions during the planning meeting and co-taught lesson. During the planning meeting, Engineering Fellow A was the dominant personality and in clear control of the direction of both upcoming units and the lesson to be taught. During the lesson, however, she took a backseat to Cooperating Teacher A and Student Teacher A, who shared lead teacher
responsibilities while she performed activities indicative of the role of Classroom Assistant. Graduate students in engineering often have little experience in elementary school classrooms, and may feel hesitant to teach young children. However, each member of a co-teaching team brings a unique perspective to the classroom, and to not engage in teaching due to lack of experience withholds from students the voice of a professional, a potential role model, and increases the workload of one’s teammates.

Intriguingly, while the engineering fellows were frequently identified as playing roles related to engineering and science content knowledge, their activities during planning and teaching were not observed to be supportive of this role. A premise of the Trinect model is that the engineering fellows bring to their triads advanced knowledge of engineering and science, and that this information would be utilized to enhance students’ STEM experiences. During planning meetings, content discussion was limited, with only Triads B and C engaging in substantive content discussions; Cooperating Teacher E and Student Teachers E very briefly discussed the nature of crustacean nervous systems in preparation for a lesson on crayfish anatomy. In Triad C, Cooperating Teacher C and Student Teacher C discussed the relationships between mass and weight and between mass and density in preparation for a lesson on the properties of air; Engineering Fellow C remained silent during these discussions. Cooperating Teacher B and Engineering Fellow B discussed the role of nutrients in plant life. During these conversations, the flow of content information was largely from Cooperating Teacher B to Engineering Fellow B; while Engineering Fellow B did look up information on his smartphone that he then shared with Cooperating Teacher B, he was not otherwise observed to share content. Interestingly, even though she was slated to lead teach during the upcoming triad lesson, during the planning meeting Student Teacher B was largely engaged in off-topic activities and was observed several
times to disrupt the conversation between her teammates. Despite his self-identified role within the triad as “addressee of misconceptions”, Engineering Fellow B himself presented a misconception view during the observed triad lesson, stating that plant color is unrelated to photosynthesis. Other than this brief foray into the fundamentals of plant life, during the co-taught lessons the engineering fellows were not observed to deliver content information. For this study, triads were observed only once during their planning meetings, and it is thus possible that in meetings not observed the engineering fellows provided a great deal more content support. One possible explanation for this is that the nature of the lesson did not support content discussions. Triads B, C, and E taught science lessons, and these were the triads in which content was discussed during planning. Triads A, D, and F facilitated engineering activities, and in these cases planning time was largely devoted to working out lesson logistics and planning for upcoming units. Despite the fact that their classes would be engaging in engineering work, no discussion of engineering content, methods, or philosophy took place; conversation in these planning meetings was limited to the logistics of the activities (e.g. in what sequence to hand out materials). Thus, although engineering fellows do possess advanced knowledge of engineering and science, their roles as STEM Content Resources and STEM Curriculum Developers may have in practice been somewhat nominal.

Effective co-teaching requires utilization of the knowledge, skill, and experience of all co-teachers; clarification of co-teaching roles helps ensure that this occurs. Members of Trinect co-teaching triads were identified as holding a variety of roles related to elementary school pedagogy and STEM content knowledge; these roles align with several of the teacher knowledge domains proposed by Shulman (1986) and were adopted by triad members in alignment with individual specializations. While the engineering graduate students were unanimously identified
in the participant interviews as STEM content and curriculum specialists, in practice their involvement with these roles may have been somewhat limited; rather than a deficit of motivation on the part of the engineering fellows, it is likely that the individual personality characteristics and the nature of the lessons being taught may have mediated the extent to which engineers fully enacted these roles.

**Role Conflicts**

Instances of role conflict were observed in two triads. Role conflict may occur internally, in which case a single individual holds roles whose functions and responsibilities conflict, or externally, wherein the conflicting roles are held by separate individuals. External role conflict was observed in two of the seven observed triads; in both cases, the conflict occurred between the engineering fellow and his or her teammates and was related to STEM content knowledge.

**Role conflict in Triad A.** Role conflict in Triad A was noted during the planning meeting and in analysis of that triad’s participant interviews. As noted above, Engineering Fellow A felt strongly that her role was to plan triad lessons for the triad; implementation of these lessons was to be carried out by her cooperating and student teacher teammates. In the observed planning meeting, Engineering Fellow A was the dominant personality and in alignment with her statements regarding her role as curriculum developer, she appeared to be in charge of determining the content and activities present in her triad’s lessons. During the planning meeting, Engineering Fellow A expressed several times her feeling that the lesson would be “too easy” for students; as such, she felt that while they should not make “things more difficult”, the triad could add additional engineering criteria or materials. Cooperating Teacher A stated that she hoped additional components would not “overcomplicate” the lesson, because “it’s [building a hand pollinator] a very simple thing” (CT, Planning Meeting, Line 10). Later in
the planning meeting, Cooperating Teacher A and Engineering Fellow A had turned to discussing an upcoming Human Body unit. Engineering Fellow A again lobbied for additional content, with Cooperating Teacher A questioning her with regard to the extent to which these new ideas aligned with district standards. During this exchange, Cooperating Teacher A used her knowledge of her 3rd grade students to act as Steward of Developmental Appropriateness; in response to Engineering Fellow A’s suggestion that their upcoming Human Body unit contain a lesson related to astronaut nutrition, she stated that she “agreed it could be simple, but some kids may struggle” (CT A, Planning Meeting, Line 120). While no evidence of resentment was observed in relation to these exchanges, the tension between Cooperating Teacher A and Engineering Fellow A may have been systemic. The interviews of Cooperating Teacher A and Engineering Fellow A showed that Engineering Fellow A felt her roles as STEM Content Resource and STEM Curriculum Developer were encroached upon by Cooperating Teacher A’s role as Steward of Developmental Appropriateness. Engineering Fellow A stated:

She was basically concerned about the amount of content that I wanted to do. She was asking a lot of questions about how they related to the standards. I didn't feel like she actually understood what the standards were about. It was causing a little bit of a conflict about trying to do human body stuff. She was trying to connect them to the standards. (EF A, Interview, Line 84)

In this passage, Engineering Fellow A appears to feel constrained by district science standards, and directly states that she does not believe that Cooperating Teacher A understood these standards. Engineering Fellow A’s statement highlights a potential danger of the Trinect approach. Published science education standards are likely to have been carefully considered and crafted to align with student capabilities. Those who have little or no experience working with young students may not possess an accurate understanding of their developmental needs; for these individuals, standards may be perceived as representing a “floor” with respect to
student abilities, rather than a “ceiling”. In these cases, additional lesson components may appear to not pose any substantive difficulties for students. While the engineering fellows all likely possess content information that would be valuable to students, teachers need to remain aware of their students’ capabilities while planning lessons and units, and have the temerity to express and defend their concerns as needed.

**Role conflict in Triad F.** Content-related role conflict was also observed in Triad F. In their interviews, Cooperating Teacher F and Student Teacher F were noted as having “strong” science backgrounds. As a result, they did not require content assistance from the engineering fellow: “[Student Teacher F] and I are, have a strong science background. So, we didn't need him to explain the science” (CT F, Interview, Line 511). Engineering Fellow F recognized this, stating with respect to Student Teacher F:

> I did see that there were points at which she [Student Teacher F] could have, I don't know, talked to me beforehand so I had to really put in effort of “send me an email if you have any questions about that”, or “I will come talk about it. So if you have any questions ask me” though, but that either never happened. (EF F, Interview, Line 337)

In this passage, Engineering Fellow F appears to express resentment that his team did not recognize his role as a content specialist. He further stated:

> At one point when we started this, I was like, "Okay we are [inaudible]. I just let her have the lead. At one point we did crash and burn. We mixed up between sources of energy and types of energy this and that, and it was super confusing, and then I had to step in during that time. I sort of had thought that after that there would be much more interaction, but yeah I didn't see any of that. (EF F, Interview, Line 348)

Engineering Fellow F continues:

> After that period when we crashed and burned, I sat down with the school teacher, explained where everything and was like, "Hey I understand it's difficult to get your head around. Just let me know if you need anything else after we're done with that." And I told her, so on Thursday or Friday, before the weekend, just send me any questions. Any questions. I'm not saying you're stuck at some point, but send me questions. That was frustrating. (EF F, Interview, Line 354)
Thus, Engineering Fellow F felt frustrated that his teammates did not turn to him for content assistance, even though a lesson had “crashed and burned”. Although this role conflict is different in nature from what was observed in Triad A, in which Engineering Fellow A was recognized as a content specialist, in both cases the engineering fellows appear to tightly guard their roles as STEM Content Resource and STEM Curriculum Developer.

Engineering fellows were unanimously identified as holding roles related to STEM content knowledge and curriculum; five of the seven triads were identified as having Stewards of Developmental Appropriateness among their members. However, role conflicts were observed in only two triads (Triads A and F). Several factors speak to the occurrence or non-occurrence of role conflicts between triad members holding roles relating to knowledge of elementary student capabilities and STEM content knowledge. First, it is possible that role conflicts did occur but were not detected by this study. Second, team member personality may have mediated the extent to which members felt that their roles had been encroached upon. Jackson and Schuler (1985) write that studies of workers involved in role conflicts indicate that personality characteristics may lead to differences in the ways individuals react to the same situation. Third, while engineering fellows were identified in the participant interviews as holding roles related to STEM content knowledge and curriculum, in practice their involvement with content knowledge appeared to have been more limited. Thus, opportunities for role conflicts may have been minimized. Many engineering graduate students likely consider their education to be important component of their self-identity; however, instances may occur in which deference to an authority from a different field may be required. While conflict was not reported in other triads, the potential did exist, and all parties must be alert to the possibility of role conflicts and strive to effectively negotiate disagreements as they arise. Fourth, triads in which role conflict was
observed may have had conflicting team mental models related to the role of content knowledge in elementary engineering and science education. Engineering Fellow A’s insistence that additional content be presented to students indicates that she may have considered dissemination of content knowledge to be the main objective of a lesson. In her role as Steward of Developmental Appropriateness, Cooperating Teacher A implicitly acknowledges that content is important, but rather than prioritizing what or how much content gets taught, her focus is how content is taught; specifically, Cooperating Teacher A’s priority was ensuring that content would be taught at a level comprehensible to her students. In essence, then, the role conflict observed between Cooperating Teacher A and Engineering Fellow A may reduce to conflicting understandings of the function of a teacher. In the case of Engineering Fellow A, the central function of a teacher to teach content. From the perspective of Cooperating Teacher A, however, it is the central function of a teacher to teach students. These mismatched role perceptions represent a conflicting team mental model regarding the function of teachers in elementary science education.

Conflicting team mental models may also help explain the role conflict in Triad F. Engineering Fellow F felt that part of his role in the triad was to explain science concepts to his teammates and when this did not occur, he felt frustrated. Team mental models facilitate teamwork by helping to ensure that each team member know what they will and what their teammates will do. When these understandings are mismatched or weakly held, conflict may occur. The co-teaching literature is rife with the prescription that co-teachers engage in dialog related to individual perspectives of teaching and learning, concomitant with the implication that perspectival agreeability will reduce the strain on co-teacher relationships pursuant to philosophical discordance. While Cooperating Teacher A and Engineering Fellow A may not
have shared an agreed upon conception of the function of the teacher in elementary science education, conversations regarding this important notion may have helped mitigate tension between them; in this case, a shared understanding may be an agreement to disagree. Had Engineering Fellow F accepted that his teammates did not require his assistance with science content, this shared perception of his role in the triad may have helped ease some of the evident frustration he felt with his teammates. Thus, recommendations made by co-teaching researchers may contribute positively to team mental model building.

**Triad Taught Lessons and Co-teaching Models**

During the initial professional development workshop, triads were introduced to a version of the five foundational co-teaching models described by Cook and Friend (1995) that were adapted to groups of three. Participants were encouraged to try a variety of models. In their lessons, however, triads were observed to use a “one teach/two assist” approach to co-teaching. This result parallels findings from studies of paired co-teachers; the “one teach/one assist” model is the model most frequently used by co-teaching pairs (Harbort et al., 2007; Friend, 2007; Rice & Zigmond, 2000; Weiss & Lloyd, 2002; Zigmond & Matta, 2004).

In this study, one triad member served as Lead Teacher, with support and assistance provided by the Supporting Teacher and Classroom Assistants. In Triad A and Triad E, the Lead Teacher role was shared between the cooperating and student teachers, while in Triad D, the engineering fellow and cooperating teacher shared Lead Teacher duties. In each of these instances, there was a clear point of demarcation between sharing of Lead Teacher responsibilities; triad members were not “sharing the stage”, but were solely responsible for significant portions of the lesson. For this reason, these lessons were not considered to be team taught.
While there was no project requirement for the use of a variety of triad co-teaching models, the default to this model coupled with the asymmetric distribution of the Lead Teacher role is intriguing. Six of the seven student teachers held the role of Lead Teacher; as described above, Student Teacher D did not substantially engage with students or assist her teammates, but instead engaged in social media messaging. Student teachers are in the final semester their undergraduate teacher licensure program; in a traditional student teaching placement, student teachers would not be sharing teaching duties, and thus one reason why the Lead Teacher role was asymmetrically distributed was related to student teachers’ status as student teachers—they may have perceived university requirements as necessitating that they be the lead teacher, even on the days when the engineering fellow was present. Despite support from both the university and school district for co-teaching, perceptions about what student teaching “should” look like may be strongly held. Participant interviews support this notion; several engineering fellows noted that they were unsure of their roles vis a vis acting as Lead Teacher, as they did not want to limit the amount of time student teachers had to perform those responsibilities. In Triad A and Triad F, the engineering fellows expressed hesitancy to act as Lead Teacher. Engineering Fellow A stated that at times she “hated” the idea of lead teaching. Engineering Fellow G expressed taking a “backseat” role during teaching, stating “when the actual teaching was happening, teachers and all, in most cases I would take a back seat for the school teacher, or the main teacher who was teaching” (EF G, Interview, Line 282). The only Engineering Fellow observed to hold the role of Lead Teacher was Engineering Fellow D. Engineering Fellow D led her students through a whole-class discussion that set the context for the triad’s “hand pollination” engineering activity. However, she had difficulty maintaining students’ focus, and several times lost control of the class, requiring the classroom management
assistance of Cooperating Teacher D. While this was an obvious example of the utilization of individual expertise required in effective teamwork, it also highlights a potential pitfall of the Trinect model. Engineering graduate students often have little experience teaching elementary school classes, and with the concomitant limitations on classroom management skills, situations similar to what was observed in Triad D may frequently occur. Thus, hesitancy on the part of the engineering fellows to adopt the role of Lead Teacher may be understandable. However, central goals of the Trinect model included opportunities for students to engage meaningfully with a STEM professional and the mutual professional growth of triad members; program goals may not be achieved if Lead Teacher duties are not more equally shared.

The “one teach/two assist” arrangement is incongruent with stated purposes and goals of co-teaching. Co-teaching represents a paradigm shift that moves away from an individual model of teaching toward a restructuring of teaching procedures to promote collaboration between individuals whose professional knowledge and experience differ (Bauwens & Hourcade, 1995). Cook and Friend (1995) write that while two adults are often present in a classroom (e.g., parent volunteers, paraeducators), co-teaching requires that all co-teachers be involved in substantive and active instruction of students; such meaningful involvement of all triad members in instruction was not observed among the co-teaching teams observed for this study. While triads may plan their lessons collaboratively, reliance on a “lead with assistants” approach to co-teaching limits the potential benefits of the triad model. Students in co-taught classrooms benefit from the unique perspectives offered by each co-teacher (Pugach & Wesson, 1995), and this is intended in the Trinect design, where one co-teacher is a STEM professional. Embury and Kroeger (2012) write that overreliance on a “lead with assistants” approach to co-teaching may create among students the perception of a hierarchy among co-teachers; the lead teacher is the
“real” teacher, while co-teachers acting in an assistive role are of lesser status. While the engineering fellows were observed very frequently to provide attention to individual and groups of students, the impact of the experience could likely have been increased had students had more opportunity to see the engineering fellows as figures of authority, rather than classroom assistants.

The issue of access to the engineering fellows as figures of authority is particularly important given the demographic characteristics of the students in the triads’ classrooms. The school district serves a high percentage of children from low-income, immigrant, and language-minority households; students in these populations are unlikely to have a parent or other close relative in STEM professions, and the engineering fellow may be their first, if not only, opportunity during their K-12 education to have such close academic interactions with an engineer.

A second goal of the Trinect model is the mutual professional growth of all triad members. Work by Roth frames co-teaching as a process of learning from an experienced other (e.g., Roth, 1998), emphasizing the co-generation of knowledge as teachers navigate and make meaning from educational situations. Preservice and inservice elementary teachers have little, if any, background in engineering, and often have little experience teaching engineering. The Trinect model is designed for cooperating teachers and student teachers to gain experience with engineering concepts and processes through collaboration with engineering graduate students; statements from participant interviews indicate that the cooperating teachers and student teachers found such collaboration to be valuable. The expertise of triad members differed widely, with engineering graduate students having no formal elementary teaching experience. Interviews with the engineering fellows indicated that they gained from the experience, including attitudinal
shifts with respect to conceptualizations of teaching, learning, and the nature of young students. That said, restrictions that were created (either by the schedule, the teachers, or the engineering fellows themselves) in the amount of time engineering fellows spent in front of students may have limited the overall impact of the experience on both the fellows and the students. Working with young children individually is one thing, but enacting the role of Lead Teacher is quite another. Each of the engineering fellows observed in this study were pursuing doctoral degrees, and may become engineering faculty members. Although there exist tremendous cognitive and behavioral differences between primary school children and tertiary-level engineering students, several of the pedagogical practices employed by elementary school teachers may be relevant in college classrooms. Engineering fellows who were limited in their use of the Lead Teacher role may have missed professional development opportunities that would serve them well in the future when they are in a teaching role.

Authentic co-teaching requires substantive involvement on the behalf of all co-teachers. Triads observed in this study all adopted a “one teach/two assist” model of co-teaching. While such an approach maximizes professional growth opportunities for the student teachers, it may do at the cost of limited impact for students and engineering fellows. Participants in co-teaching triads should be encouraged to consider co-teaching models that distribute Lead Teacher responsibilities in a more equitable manner.

Mismatch Between Perceived and Enacted Roles

Triad member roles were observed to correspond to their identity within their triads (i.e., cooperating teacher, student teacher, or engineering fellow). However, in some instances, a gap existed between the perceived role held by an individual or participant group and their enactment of that role, as observed in the planning meetings and co-taught lessons. This result echoes work
by Austin (2001), who noted that while co-teachers expressed placing a high value on certain aspects of the co-teaching process, the extent to which these aspects were enacted was sometimes limited.

The engineering fellows participating in this study were unanimously perceived, by both themselves and their teammates, as holding roles related to STEM content and curriculum development. However, observations of triad planning meetings and co-taught lessons indicate that in practice, the extent to which engineering fellows engaged directly in content and curriculum support may have been somewhat limited. Of the 6 triads observed during planning meetings in this study, only 2 engaged in substantive content discussion (Triad B and Triad C), and in only one of these (Triad B) did the engineering fellow participate; in this case, however, the net flow of content information was from Cooperating Teacher B to Engineering Fellow B. During this planning meeting, the triad was preparing for a lesson on the function of plant anatomy with respect to the overall health of the plant. Engineering Fellow B was unsure of the terms used to describe parts of the plant (e.g., cotyledon), so Cooperating Teacher B explained to him the vocabulary words as would be presented to students, as well as the role of these features of plant anatomy. In addition, Engineering Fellow B was not a native speaker of English, and had difficulty with several of the English terms for plant characteristics; Cooperating Teacher B was observed to assist him with these difficulties.

With respect to STEM curriculum planning, only Engineering Fellow A was observed be substantively involved. During Triad A’s planning meeting, Engineering Fellow A shared with her triad her vision for the direction the triad should take in an upcoming unit on the human body. In the remaining triads, engineering fellows were observed to act as passive observers
during the planning meeting or assist in procuring lesson materials and working out lesson logistics, despite their perceived roles as STEM Curriculum Developers.

Several explanations exist for this mismatch between the engineering fellows’ perceived and enacted roles. First, triads were observed during only one planning meeting; engineering fellows may have been engaged in content-related activities during planning meetings not observed for this study. Second, of the 7 co-taught lessons observed for this study, only 2 were science lessons; these lessons were taught by Triad B and Triad C, which were also the only triads to discuss science content during the planning meeting. Additionally, those triads that did not teach science lessons led hands-on engineering activities designed to highlight aspects of the process of engineering design; in these cases, there was little science or engineering content to be discussed. Thus, the nature of the lesson may have worked to preclude content-sharing by the engineering fellows. Finally, the science lessons taught by the triads were expected to support the district’s science goals; in support of these goals, the district employed the Full Option Science System (FOSS) curriculum package. Each FOSS unit contained extensive content background for teachers, and thus engineering fellows may not have been observed to engage in content-related activities due to the presence of content material in the curriculum. Thus, while the engineering fellows possessed high-level knowledge of science and engineering fields, such knowledge was not required, as they considered the content presented by the FOSS unit adequate for their triad’s instructional goals and objectives. This example highlights the difference between general content knowledge and content knowledge for teaching; while the former may be expert knowledge of a narrow science or engineering discipline, the latter represents not only content knowledge but includes with it an understanding of how that knowledge will function in the classroom (e.g., student misconceptions, areas with which students experience difficulty).
A further mismatch may have occurred within the cooperating teacher participant group. The cooperating teachers were unanimously perceived, by themselves and by their teammates, to hold the role of Experienced Teacher. However, during the observed co-taught lessons, the cooperating teachers played the corresponding role of Lead Teacher infrequently; the student teachers were approximately twice as likely to enact the role of Lead Teacher as the cooperating teachers. Several possible explanations exist for this mismatch between perceived and enacted roles. First, the student teachers were in the final semester of an undergraduate teacher education program; cooperating teachers may have deferred to the student teachers with respect to the role of Lead Teacher based on a shared perception that, as preservice teachers, the student teachers should be given the majority of the “up front” time. However, the role of Experienced Teacher was coded as more encompassing than acting as a lead teacher during instruction; Experienced Teachers also described providing classroom management and logistics support to their teammates and using their knowledge of students to design developmentally appropriate lessons. Thus, while the cooperating teachers were not frequently observed in the Lead Teacher role, in less visible ways there were still able to leverage their expertise for the benefit of their triads.

Members of Trinect triads were observed to play roles that, in general, aligned with their identity within their triad; in some instances, however, the roles triad members were perceived to play, by themselves and their teammates, were not congruent with their observed actions and statements during collaborative planning. This observation highlights the complex nature of team dynamics and underscores the need for shared understandings of roles among team members. Perceptions of the engineering fellows as STEM content and curriculum specialists relayed during participant interviews may have been reflective of individuals’ conceptions of engineers as isolated identities, rather than members of a co-teaching team. Within Trinect co-
teaching triads, curriculum packages and other triad members also provide content and curriculum support, thus exemplifying the notion of “team” while simultaneously limiting the contributions of the engineering fellows. Future triads are encouraged to work toward shared understandings of the role of content in their triads and work toward ways to more substantively include the content expertise of the engineering fellows.

**Implications**

This study has implications for the integration of STEM professionals in elementary school classrooms, shared mental models research, and elementary science teacher education.

**STEM Professionals as Content Experts**

A central tenet of the Trinect model was the synergistic integration of individual areas of knowledge, skill, and experience to produce a rich STEM learning environment; engineering and science content knowledge and experience brought by the engineering fellows was crucial to creating such an environment. While triads were to remain within the scope and sequence of the school district’s science curriculum, they were given free rein to integrate additional topics and content within the limits of logistical and developmental feasibility. In the participant interviews, engineering fellows were unanimously identified as playing roles related to STEM content knowledge and curriculum development; observations of collaborative planning meetings and co-taught lessons, however, showed that in practice, the extent to which the engineering fellows actually engaged in content-related activity may have been limited.

The use of STEM professionals in K-12 classrooms is often encouraged because of the high level of content knowledge they may bring to the learning environment. In this study, the engineering fellows possessed a high level of content knowledge about their specific discipline, but had content knowledge gaps in areas outside their expertise. The project addressed this issue
with the engineering fellows to ensure they were not caught off guard when grade 3-5 science content was something they needed to study. Some engineering fellows mentioned the need to study long-forgotten content, and other engineering fellows were observed teaching content incorrectly.

In addition, even if the expertise of the engineering fellows encompasses the topics being taught in elementary schools, it is at a level of depth and complexity that may not readily translate into developmentally appropriate elementary science and engineering lessons. The roles developed by triad members provide insight into a tension between “content” and “content for teaching”. The proliferation of the role of Steward of Developmental Appropriateness among the cooperating and student teachers in this study is likely a result of a disparity between expert-level knowledge and a knowledge of subject matter that is appropriate for students. Conflict occurred when this gap could not be successfully crossed. For example, Engineering Fellow A wanted to include additional content, and did not understand the resistance she encountered from her cooperating teacher. Even though this misalignment may not have resulted in observable conflict, its presence between engineering fellows and cooperating and student teachers may have been widespread, given the number of cooperating teachers and student teachers who felt that it was their role to “filter” concepts and activities too advanced for their students. In this sense, while the engineering fellows were often considered “content experts”, cooperating and student teachers may be considered “student experts” and a key function of the triad is to develop subject matter knowledge appropriate for teaching. Thames and Ball (2010), writing from the perspective of mathematics education, observe that

Mathematical knowledge does matter for teaching. But it is not a mathematical expertise like that required for research in mathematics or for other kinds of quantitative work. Instead, mathematical knowledge for teaching is a kind of
complex mathematical understanding, skill, and fluency used in the work of helping others learn mathematics. (p. 220)

This knowledge base, termed “mathematical knowledge for teaching” likely has a counterpart in science and engineering education. Elementary teachers’ discomfort and lack of preparation in science and engineering has been well-documented (e.g., Banilower et al., 2013). Triads are thus faced with a dilemma—how to transform the expert knowledge possessed by the engineering fellow into a form that is accurate, developmentally appropriate, and aligned with elementary science standards. This requires that teachers be aware of the extent of their science and engineering content knowledge and be open to learning new content that they may find challenging.

Simultaneously, they must leverage their understanding of students and their learning processes, curriculum materials, and the constraints of the school setting. At the same time, the engineering fellows must be open to the possibility of gaps in their content knowledge or the presence of misconceptions and work to articulate their content expertise in a way that is accessible to persons outside their field. These tasks are not easily accomplished; research on expertise makes clear that experts structure knowledge in ways that are very different from those of novices, and that their expertise may become automated over time (Bransford, Brown, & Cocking, 2000). Thus, engineering fellows may struggle to adapt high level content knowledge to elementary school settings, and teachers may struggle to articulate to the engineering fellows how children learn or why particular activities or content will not be successful with their students.

**Realizing the Potential of Co-Teaching**

During the co-taught lessons, the function of the engineering fellows centered on supporting and assisting the lead teacher; as described above, this limited engagement may
lessen the potential benefits available for both participants and students. Programs desiring to integrate STEM professionals into elementary science classrooms should therefore consider beforehand the roles these professionals will play, and consider ways to either employ more team teaching structures, or ensure that lead teacher duties include the STEM professional. If STEM professionals will be directly engaging with students, substantive preparation in the methods and philosophy of elementary science education would be necessary. If co-teaching will be undertaken, ongoing professional support may be necessary to ensure that authentic co-teaching occurs throughout the experience. Thus, programs should be ready support STEM professionals, both in terms of the philosophy and methods of elementary science education and also the practices and interpersonal skills required for authentic co-teaching.

**Limitations and Further Research**

Several limitations exist with respect to the findings of this study. Most notably, triads were observed during only a single planning meeting and a single co-taught lesson, providing only a snapshot of the roles present in triads as observed through the actions of triad members; further observations would have allowed for a more thorough exploration of role categories and a possible investigation of relationship roles. Further, theories of team development imply that teams progress through discrete stages as member relationships evolve; to ensure approximate fidelity of developmental stage, triads were all observed near the end of the semester. Triads observed at different points in the semester may exhibit different role dynamics. For instance, student teachers take on increasing responsibility for solo-teaching as the semester progresses; had triads been observed closer to beginning of the semester, the majority of the Lead Teacher responsibilities may have been carried out by another triad member, likely the cooperating teacher. Furthermore this study reported findings relating a specific composition of triad. Co-
teaching triads composed of, for instance, a grades 3-5 cooperating teacher, a special education teacher, and a graduate student in engineering may enact different roles and display a different role distribution.

Findings from this study illuminate potential inquiries for further research. First, this study examined the roles played by members of Trinect co-teaching triads as exemplified by member actions, but did not consider the extent to which these actions were of high quality. Thus, what levels of performance quality were reached by members of Trinect co-teaching triads? Second, how triad members came to play the roles they were observed to hold is unknown. Future studies of co-teaching triads may investigate the role adoption or assignment processes present in triads. Finally, the use of other communication tools employed by triads in planning, such as Google Documentss and text messaging, could be examined to determine the extent to which engineering fellows engaged in content-related activities that were not detectable using the methods of this study.

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CHAPTER 4. TEAM EFFECTIVENESS OF SCIENCE AND ENGINEERING CO-TEACHING TRIADS

ABSTRACT

Team effectiveness is a multi-dimensional construct reflecting the degree of performance quality achieved by a team and team member attitudinal and satisfaction-related perspectives. Specifically, this study operationalized team effectiveness as triads’ composite scores on a science lesson evaluation instrument and aggregated triad member satisfaction ratings related to triad lesson planning and implementation activity. Triads were related as Effective, Moderately Effective, or Ineffective. Results indicate that triad team effectiveness was impacted by the extent to which triads engaged in surfacing student prior knowledge, use of evidence, and sense making of targeted ideas. Implications for elementary science teacher professional development are discussed.

Introduction

Elementary science teachers face many challenges in teaching science. First, their teacher education programs are unlikely to include sufficient science content to enable them to feel comfortable and confident with their science content knowledge (Banilower et al., 2013). Furthermore, time for science has been dwindling since 2001 as increasing emphasis is placed on language arts and mathematics (Center for Education Policy, 2007). Adding to the challenge is the recent release of the Next Generation Science Standards (NGSS) that expect engineering to be taught alongside science content in grades K-12. Only 1% of elementary teachers have taken coursework in engineering (Banilower et al., 2013).

To address this challenge, simply adding additional coursework to elementary teacher education programs is unrealistic. Such programs prepare teachers to teach between 4-7 subjects
and are already overtaxed; they must address content knowledge across multiple subjects as well as pedagogy, learning theory, field placements, and other state-mandated coursework in subjects such as instructional technology, diverse learners/special education, historical and/or philosophical foundations of education (Olson, Tippett, Milford, Ohana, & Clough, 2015). One solution to this problem is to view field placements such as student teaching as an opportunity to engage in targeted professional development in science and engineering. The Trinect project is an NSF-funded effort that included a novel format for student teaching. Trinect student teachers were placed with a cooperating teacher in a grade 3-5 urban setting with an engineering graduate student who was with the pair one full day per week, forming a co-teaching triad. This study investigates the effectiveness of the triad model.

**Literature Review**

Trinect co-teaching triads were tasked with implementation of the district’s science curriculum; as the district has adopted NGSS, engineering is expected to be a component of school science programs. The use of triads is predicated on the notion of distributed expertise. Each triad member brings a unique set of skills and knowledge, and the intent of the triads is to combine these individual specializations to create a STEM learning environment that exceeds what could be accomplished by any individual member, resulting in professional growth for all individuals. To accomplish this, triads engage in co-teaching. Co-teaching is most frequently associated with special education (Badiali & Titus, 2010), but it has also been successfully employed in general education content teaching (e.g., Cacciatore & Morey, 2017; Moorehead & Grillo, 2013) and as a vehicle for preservice teacher development (Bacharach, Heck, & Dahlberg 2008, 2010; DelColle & Keenan, 2015). While most published studies of co-teaching report findings related to paired co-teaching, and thus are not expected to be directly applicable to triad
co-teaching, an understanding of the fundamentals of paired co-teaching represents a starting point to investigate the functioning of co-teaching triads.

**Co-teaching**

Co-teaching occurs when two or more teachers share instructional responsibility for a single group of students in a single physical space (Cook & Friend, 1995). Co-teaching is predicated on the notion that multiple teachers reduce the teacher-to-student ratio, resulting in more individualized instruction, increased opportunity for students to respond, and enhanced classroom management (Sweigart & Landrum, 2015). Co-teachers share responsibilities related to collaborative planning of co-taught lessons, shared instruction of students, and co-assessment of student work (Murawski, 2003). While empirical findings supporting co-teaching as a research-based practice have been limited (Cook, McDuffie, Oshita, & Cook, 2011; Murawski & Swanson, 2001; Volonino & Zigmond, 2007), co-teaching continues to be widely used in both elementary and secondary schools, both in the United States and internationally (Gable, Mostert, & Tonelson, 2004; Rice & Zigmond, 2000).

**Studying Co-Teaching**

Due to the presence of multiple teachers in a co-taught classroom, studying co-teaching is more complex than studying a single teacher. Co-teachers must not only select content, materials, activities and strategies, but they also have at their disposal a range of co-teaching models from which to choose, and different teachers can take different roles within these models (Cook & Friend, 1995). The choice of co-teaching model may influence both student and teacher self-efficacy and performance (Embury & Kroeger, 2012; Keefe & Moore, 2004; Weiss & Lloyd, 2002). Murawski and Lochner (2011), also note that the presence of multiple professionals in a single classroom should create a learning environment that is substantively
more rich than what is attainable by a single teacher. Studying such environments necessitates the detection of the extent to which co-teachers integrate individual specializations in support of their learning goals.

Although studying co-taught classrooms presents particular challenges, little has been written that addresses components required for effective evaluation of a co-teaching environment (Wilson, 2005). Salend, Gordon, and Lopez-Vona (2002) provide a set of guidelines and strategies for use by administrators to use in co-teacher evaluation, which includes teacher interviews, surveys and observation of co-taught classes. While the authors describe a general approach to co-teacher evaluation, they do not provide a set of research-based criteria that may inform study of co-teacher performance. Work by Wilson (2005), Magiera and Simmons (2005), and Murawski and Lochner (2011) includes co-teaching evaluation instruments grounded in both theoretical and practical aspects of co-teaching research. Wilson (2005) describes an evaluative framework that examines the teachers’ roles during co-taught lessons, the strategies co-teachers use to promote student success, and evidence of student growth and presents an evaluation instrument founded on classroom observations. The Magiera-Simmons Quality Indicator Model of Co-teaching arose from a university-school district research partnership (Magiera, Simmons, Marotta, & Battaglia, 2005) and was created as an evaluation tool for evaluators and mentors working in co-taught classrooms (Magiera & Simmons, 2005). This instrument rates co-teachers on five domains of professional practice: Professionalism, Classroom Management, Instructional Process, Learning Groups, and Student Progress; benchmarks are provided for observation of co-taught classrooms and guidelines for teacher and evaluator reflection. Murawski and Lochner (2011) provide a research-based co-teaching evaluation instrument centered on three core elements of co-teaching: collaborative planning, co-instruction, and co-assessment. The
instrument provides lists of “ask for, look for, and listen for” items, including collaborative lesson plans, evidence of shared instructional responsibilities, and use of parity language in co-teacher conversations and teaching.

Research on co-teaching indicates that co-teachers value interpersonal compatibility and the ability to work together in a harmonious manner. Similarly, work in organizational psychology indicates that teamwork skills and abilities are frequently as determinative of team success as the technical task knowledge possessed by the team’s members (Hollenbek, DeRue, & Guzzo, 2004), while Hackman (1987) cites team member relationships as a factor crucial to a team’s viability. The co-teaching evaluation instruments described above may be useful for administrators in an evaluative role by focusing on rating the performance and collaborative aspects of co-teaching. However, their utility for research on co-teaching is severely limited because they do not address the relationships between co-teachers and the nature of interpersonal dynamics and their impact on classroom performance.

To understand functionality of co-teaching triads, the ability to assess member relationship characteristics is particularly important given that three relationships are involved rather than one. Trinect triads also possess other traits that may not be typical of co-teaching pairs. For example, within Trinect co-teaching triads, the cooperating teacher has an influence on the student teachers’ university grade for student teaching, creating differences in perceived social power. Additionally, the individual specializations possessed by the cooperating teachers and engineering fellows may lead to competing centers of influence within the triad, and attempts to merge knowledge bases may create confusion between co-teachers (Sileo, 2011). Interpersonal dynamics are known to be affected by differences in perceived social power (French & Raven, 1959), and may result in dissent and “two against one” coalition formation.
within triads (Caplow, 1968; Simmel, 1950). Further, unresolved issues between co-teachers may interfere with co-teachers’ ability to collaborate on behalf of students (Sileo, 2011). Thus, a need exists for a research framework that addresses both classroom performance and characteristics of the interpersonal relationships between co-teachers.

**Conceptual Framework**

Members of Trinect triads engage in co-teaching. Effective co-teaching requires a combination of individual resources and positive teamwork skills (Cook & Friend, 1995). Co-teaching performance may be influenced by the distribution of content knowledge and pedagogical skill in a co-teaching relationship (Friend & Cook, 2000), and it was the purpose of this study to better understand how differences in professional and educational preparation interact in the context of the classroom. In particular, this study investigated the performance effectiveness of triad-taught elementary school science lessons. However, effective teams do more than simply perform their tasks at a high level of quality; they must do so in a manner that promotes healthy team member relationships and high levels of member satisfaction with team functionality. Thus, this study also investigated triad-level and individual-level satisfaction with respect to collaborative planning and triad-taught lessons.

Trinect co-teaching triads exemplify the construct of work teams. Members of work teams interact socially, share common goals and accountability for achieving those goals, and exhibit autonomy in terms of task performance (Banker, Field, Schroeder, & Sinha, 1995; Kozlowski & Bell, 2003; Levi, 2007). The knowledge and skill required to accomplish team tasks is distributed among team members, and team members combine individual effort and resources to accomplish the collective task (Mohammed & Ringseis, 2001). Given the disparities of professional and educational backgrounds present in Trinect co-teaching triads,
analysis of triad performance and satisfaction from the perspective of organizational psychology is appropriate. Thus, this study adopted the functional perspective of small-group research (Poole et al., 2004). The functional perspective examines groups in terms of the factors that impact group performance and seeks to identify the activities and behaviors that both promote and detract from group effectiveness. Working from this perspective, it was the purpose of this study to determine what aspects of triad science lesson implementation impacted team effectiveness. In addition, this study also investigated the distribution of satisfaction with triad lesson planning and implementation both across and within triads.

Trinect co-teaching teams work collaboratively to plan and implement elementary engineering and science lessons that support district science standards. Highly performing Trinect co-teaching triads implement research-based science and engineering education practices. With respect to elementary school science teaching, effective instruction includes opportunities for students to work on meaningful scientific problems, the surfacing of prior knowledge of natural phenomena to connect previous understandings to new material, and use of scaffolding techniques to guide student conceptual development of science concepts (National Academies Press, 2007). Further, effective science instruction promotes conceptual development through a focus on dialogue and student meaning-making (Driver et al., 1994). However, a triad’s ability to plan and teach science lessons may be hindered by inability to collaborate effectively. Team member satisfaction is a team emergent state (Jehn et al., 2008) reflecting the composite perception of relationships and interactions among team members (Kong, Konczak, & Bottom, 2015). Team members have a variety work-related needs which the team may satisfy, ignore, or frustrate; members of triads that meet these needs are more likely to feel satisfied with team performance than members of triads that do not.
A construct that addresses the dual nature of co-teaching team performance is *team effectiveness*. With respect to the notion of team effectiveness, performing the team task in an exemplary manner is not enough; in addition to high quality task performance, effective teams promote positive interpersonal relationships and individual satisfaction among team members. Assessing team effectiveness thereby requires both a set of criteria used to assess quality of task performance and measures of the attitudinal and satisfactional disposition of team members. In the context of this study, the effectiveness of Trinect co-teaching teams was assessed in terms of Team Performance and Team Satisfaction. Team Performance was represented by the composite score received by a triad on a science lesson evaluation instrument. Team Satisfaction was represented by the mean triad member rating on a set of Likert items addressing satisfaction with triad lesson planning and implementation. These scores were combined to create a single Team Effectiveness rating. The research questions guiding this study were: (1) What levels of team performance were achieved by Trinect co-teaching triads during a 16-week professional development program?; (2) How was satisfaction with team lesson planning and implementation distributed within and across triads? (3) What levels of team effectiveness (performance + satisfaction) were achieved by the Trinect triads?

**Study Context and Participants**

This study reports findings from a 16-week science and engineering preservice teacher education professional development program that formed a partnership between a university and a large urban school district. Engineering graduate students from a large public university were paired with a cooperating teacher/student teacher pair to form co-teaching triads in grades 3-5 classrooms. Engineering fellows spent one full school day per week working with the cooperating/student teacher pair and assisted in planning and implementation of the district’s
science curriculum; the district had adopted NGSS and thus engineering was expected to be a component of school science programs. Ten triads participated each semester. Engineering fellows participated for a full academic year (two 16-week placements), while the student teachers and cooperating teachers participated for only one 16-week placement; thus, new triads were formed each semester. During the semester, participants attended two professional development workshops conducted by project leadership. In addition, the engineering fellows met weekly with university science education and engineering faculty to discuss relevant aspects of science and engineering education.

Data for this study were collected for five semesters between the Fall 2015 - Fall 2017 semesters. Complete data sets were available for 32 participant groups, including 31 triads and 1 dyad. For the Fall 2015 and Spring 2016 semesters, triads were formed by random assignment. For the remaining semesters, triad assignments were based on a professional and personal compatibility assessment administered by Target Training International (Target Training International, 2014). The IRB exempt approval memo is contained in Appendix 2.

School District

The study took place in a large urban school district serving a highly diverse student population. Co-teaching triads taught in 18 elementary schools, with 15 of these schools hosting multiple triads. The schools in the study ranged from 24-95% of students qualifying for free/reduced lunch. The district had recently adopted NGSS, with the concomitant expectation that engineering be integrated into school science programs.

Participants

In total, 79 individuals participated in this study; represented are 28 cooperating teachers, 20 engineering fellows, and 31 student teachers.
Cooperating teachers. Cooperating teachers were recruited for the project by the district’s science curriculum coordinator and participated for one 16-week semester. The cooperating teachers taught in grades 3-5 classrooms and represented a range of teaching experience and degree of comfort and background teaching science and engineering. Four cooperating teachers participated twice: two in the Fall 2016 semester and two in the Fall 2017 semester.

Student teachers. Student teachers were all in the final semester of an elementary education undergraduate degree and licensure program. Student teachers were recruited through informational meetings held by project personnel and submitted an application; no special experience with engineering or science was required. Acceptance decisions were made by project administrative personnel and were based on professionalism in past coursework and field placements as verified by program faculty members. Subsequent to her acceptance into the program, one student teacher was reassigned to a different cooperating teacher; her cooperating teacher and engineering fellow teammates continued to work as a dyad.

Engineering fellows. The engineering fellows were made aware of the program through informational emails and word-of-mouth and were accepted for participation based on results of interviews with project leadership. Engineering fellows were active members of university research groups and thus participation was contingent on permission from their major professors. Participating engineering fellows represented a wide range of engineering fields and were all in the second year or later of M.S. or Ph.D. programs. Engineering fellows participated for a full academic year (two 16-week semesters), working with a new cooperating/student teacher dyad each semester. Nineteen engineering fellows participated in this study, two of whom were repeat participants.
Professional Development

Participants attended professional development workshops conducted by project leadership, which included university faculty in science education, mathematics education, and engineering. The workshops had several goals: First, enhance participants’ understanding of effective elementary science and engineering instruction. Second, enhance participants’ understanding of the nature of engineering and the nature of science, including similarities and differences across these two disciplines. Third, help participants understand their roles in the triad and co-teaching models they could use throughout the semester in their work together. Fourth, help participants learn about the strengths each person brings to the team and get to know one another. Finally, participate in planning activities with the support of project staff and other triads.

The first workshop occurred 3 weeks prior to the start of the semester, and during the summer, included three days for the engineering fellows only, with the purpose of addressing legal issues of working in schools and to prepare them for their work with teachers and young students. This was followed by two days where all triad members were present. This 2-day workshop was also provided for spring semester triads. During this time, triads received instruction and participated in activities related to NGSS-aligned elementary engineering and science education, triad roles and responsibilities, and long-range unit planning; time was also allotted for team-building experiences and a tour of the engineering fellows’ research facilities.

A day-long professional development workshop was held for the cooperating teachers and student teachers near the midpoint of the semester. This workshop focused on improving engineering and science concept development practices through design of unit- and lesson-level
content sequencing and included opportunities for participants to apply these ideas in an engineering context.

The engineering fellows received additional support throughout the semester. Fellows participated in an hour-long seminar led by science education and engineering faculty members. These sessions provided the opportunity for fellows to share with each other classroom successes and challenges and also served as a medium for ongoing professional development through instruction on engineering and science-related pedagogical practices.

Methodology

Data Collection

In the context of this study, team effectiveness consists of two domains: team performance and team member satisfaction. Team performance was assessed based on observations of triad-taught science lessons. Team member satisfaction was measured using participant responses to Likert-scale survey items.

Science lesson evaluations. Triads taught science and engineering lessons and were observed throughout the semester by two research assistants. At least once per semester, researchers completed a formal observation of a science lesson using the Assessing the Impact of the MSPs (AIM) instrument (Horizon Research, 2015). The AIM instrument is a classroom observation protocol that examines six domains of instruction: Science Content, Opportunities to Surface Prior Knowledge, Engaging with Examples and Phenomena, Using Evidence to Draw Conclusions and Make Claims About the Phenomena, Sense Making of the Targeted Idea, and Classroom Culture. A list of Likert-scale items was used to score each domain based on the likelihood of various instructional practices to meet the targeted goals of that domain. After rating the lesson on the Likert items, each domain is assigned a final score representing the
likelihood that instructional practices related to the domain supports student learning of the targeted idea. Researchers were trained on the instrument by the instrument developers and acceptable levels of intercoder agreement for each domain were established. Data collection extended over 5 semesters, during which time 50 triads participated in the program. Triads taught both engineering and science lessons. Because the AIM instrument was designed for use with science lessons, and for the sake of making appropriate comparisons, engineering lessons were excluded from the present study. Of the 50 participant triads observed, analysis of a science lesson using the AIM instrument was completed for 32 triads.

**End-of-semester survey.** Participants responded to a survey given at the end of the semester that measured member attitudes related to aspects of lesson planning and implementation and the ability of triads to work together; surveys consisted of Likert-scale and free-response questions. Surveys were distributed electronically three weeks prior to the end of the semester. A subset of questions from this survey were used to determine triad member satisfaction with team lesson implementation and collaborative planning processes. Survey questions chosen for this analysis were: (1) “On a scale of 1-10, how satisfied were you with what you were able to accomplish with science and engineering this year?”; (2) “On a scale of 1-10, how satisfied are you with the planning process that your triad employed?”; (3) “On a scale of 1-10, how effective do you think your planning process was?”; and (4) “On a scale of 1-10, how satisfied are you with the way your triad taught science and engineering?” Participants explained their choice of satisfaction ratings in response to open-ended questions. A text box was provided below each of the questions listed above, with the following prompt: “Please explain your answer to the previous question.” Collection and analysis of survey data was carried
out by Trinect research personnel. Complete survey responses were available for 72 of the 79 participants.

Data Analysis

Operationalizing team performance. Team Performance was operationalized as the aggregated performance ratings from the six instructional categories assessed by the AIM classroom observation instrument. Team performance ratings for each domain of the AIM instrument were assigned a 4-point Likert scale (1-4, low to high). The internal consistency of a set of assessment items reflects the extent to which responses to items share a common cause (DeVellis, 2003); in the context of this study, internal consistency refers to the degree to which the six domain ratings of the AIM instrument reflect the overall performance of a triad during the observed science lesson. Cronbach’s alpha for the six team performance items was 0.75; this value indicates that the internal consistency of these items is acceptably high (Tavakol & Dennick, 2011). Ratings on each performance sub-scale therefore were summed to create a single Team Performance Score (P) for each triad; Team Performance Scores could range between a minimum of 6 and a maximum 24. Triads were assigned ratings reflecting levels of performance effectiveness with respect to their Team Performance Score; these categories were High Performance, Moderate Performance, and Low Performance. Score intervals for these characterizations are listed in Table 1.

Table 1. Team performance ratings

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<th>Team Performance Score (P)</th>
<th>High Performance</th>
<th>Moderate Performance</th>
<th>Low Performance</th>
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<td>P ≥ 18</td>
<td></td>
<td>13 ≤ P ≤ 17</td>
<td>P ≤ 12</td>
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Operationalizing team satisfaction. Likert responses from the survey were analyzed. Cronbach’s alpha for the four team satisfaction items was 0.87; this value indicates that the internal consistency of these items is acceptably high (Tavakol & Dennick, 2011); responses to
these items thus target a common construct. At the individual level, member satisfaction with discrete elements of team performance may interact in such a way as to create a composite sense of performance satisfaction; this composite sense of satisfaction may be increased or decreased by satisfaction extremes. For instance, a triad member may be satisfied with her team’s ability to engage productively in lesson planning, but highly dissatisfied with the implementation of those lessons; her composite sense of team performance satisfaction may thus be decreased despite her perception that her team could work together efficiently. Composite quantities affected by the presence of outliers parallel the properties of mathematical averages. Accordingly, the mean of the four individual satisfaction ratings was used to represent individuals’ composite satisfaction with respect to collaborative planning and lesson implementation.

**Aggregating team satisfaction.** Triad member mean satisfaction scores represent individual-level constructs; individual average satisfaction scores were then aggregated to represent the team-level perception of satisfaction with triad lesson planning and implementation. Within groups, members will have a maximum, minimum, and mean for satisfaction, and for each group, a unique distribution will exist (Williams & Sternberg, 1988). Common methods used to combine individual characteristics to create team-level aggregates are to consider the maximum, minimum, and mean of individual quantities (Barrick, Stewart, Neubert, & Mount, 1998; Williams & Sternberg, 1988). Using individual extremes to represent an aggregate response implies that the satisfaction of a single individual is sufficient for understanding the dynamics of the team with respect to satisfaction. However, such an approach excludes individuals with higher or lower scores. Representing a team-level response with the mean of individual responses implies that individual levels of satisfaction interact to increase or decrease the collective pool of that characteristic (Barrick et al., 1998); from this perspective, it
is assumed that team effectiveness will be impacted by more or less of a given characteristic. However, this aggregation method excludes specific information about individual team members.

Team-level satisfaction may be represented more or less well by different methods of aggregation. Here, team-level satisfaction was considered to be a function of the satisfaction ratings of all team members; in this case, the perceptions of more satisfied team members balance those of less satisfied members. Thus, the aggregated Team Satisfaction score for a triad was the mean of all individual satisfaction ratings across all triad members. This quantity was denoted $S_{\text{mean}}$. Co-teaching teams were categorized as being Satisfied, Moderately Satisfied, or Dissatisfied. Table 2 displays the score intervals for these categories.

<table>
<thead>
<tr>
<th>Satisfied</th>
<th>Moderately Satisfied</th>
<th>Dissatisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{\text{mean}} \geq 7$</td>
<td>$5 &lt; S_{\text{mean}} &lt; 7$</td>
<td>$S_{\text{mean}} \leq 5$</td>
</tr>
</tbody>
</table>

**Operationalizing team effectiveness.** Teams were assigned a Team Effectiveness rating of Effective, Moderately Effective, or Ineffective based on combined Team Performance and Team Satisfaction ratings. Team effectiveness categories are listed in Table 3.

<table>
<thead>
<tr>
<th>High Performance</th>
<th>Satisfied</th>
<th>Moderately Satisfied</th>
<th>Dissatisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate Performance</td>
<td>Effective</td>
<td>Moderately Effective</td>
<td>Moderately Effective</td>
</tr>
<tr>
<td>Low Performance</td>
<td>Ineffective</td>
<td>Ineffective</td>
<td>Ineffective</td>
</tr>
</tbody>
</table>

Table 2. Team satisfaction ratings.

Table 3. Team effectiveness categories.
Results

Research Question 1: What levels of team performance were achieved by Trinect co-teaching triads during a 16-week professional development program?

Team Performance was rated as the composite of six indicators of science teaching effectiveness: Science Content, Opportunities to Surface Prior Knowledge, Engaging with Examples/Phenomena, Using Evidence to Draw Conclusions and Make Claims About the Phenomena, Sense Making of the Targeted Idea, and Classroom Culture. Team Performance categories were High Performance, Moderate Performance, and Low Performance. Team Performance scores and ratings are listed in Table 4. Ten triads were rated as High Performance, sixteen triads were rated as Moderate Performance, and six triads were rated as Low Performance.

Table 4. Team performance scores and ratings.

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Team Performance Score (P)</th>
<th>Team Performance Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>Moderate</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>Moderate</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>High</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>Moderate</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Low</td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>Moderate</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>Moderate</td>
</tr>
<tr>
<td>13</td>
<td>21</td>
<td>High</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td>Moderate</td>
</tr>
<tr>
<td>15</td>
<td>19</td>
<td>High</td>
</tr>
<tr>
<td>16</td>
<td>13</td>
<td>Moderate</td>
</tr>
<tr>
<td>18</td>
<td>13</td>
<td>Moderate</td>
</tr>
<tr>
<td>19</td>
<td>11</td>
<td>Low</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>Moderate</td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td>High</td>
</tr>
<tr>
<td>23</td>
<td>14</td>
<td>Moderate</td>
</tr>
<tr>
<td>25</td>
<td>9</td>
<td>Low</td>
</tr>
<tr>
<td>26</td>
<td>18</td>
<td>High</td>
</tr>
<tr>
<td>27</td>
<td>13</td>
<td>Moderate</td>
</tr>
<tr>
<td>28</td>
<td>18</td>
<td>High</td>
</tr>
<tr>
<td>31</td>
<td>10</td>
<td>Low</td>
</tr>
<tr>
<td>35</td>
<td>15</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
The maximum Team Performance score was 22 and the minimum Team Performance score was 9. The mean Team Performance score was 14.8 and the standard deviation was 3.5. Team Performance mean scores and standard deviations for each level of performance are reported in Table 5.

Table 5. Team performance scores.

<table>
<thead>
<tr>
<th>Team Performance</th>
<th>High Performance</th>
<th>Moderate Performance</th>
<th>Low Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td>19.1 (1.5)</td>
<td>14.3 (1.8)</td>
<td>10.8 (1.4)</td>
</tr>
</tbody>
</table>

One-way analysis of variance indicated significant differences in science lesson evaluation scores exist between the three performance effectiveness categories, $F(2, 29) = 57.8$, $p < 0.001$, $\alpha = .05$. Post-hoc comparisons with the Tukey HSD test indicated that the mean science lesson evaluation score for the High Performance triads was significantly higher than the mean science lesson evaluation scores for both the Moderate Performance and Low Performance triads. Post-hoc analysis with the Tukey HSD test further indicated that the mean science lesson evaluation scores for the Moderate Performance triads were significantly higher than those for the Low Performance triads.

Team Performance was rated on the six instructional domains of the AIM classroom observation instrument. Mean domain scores and standard deviations are reported in Table 6.
Table 6. AIM domain scores by performance effectiveness category (Mean(SD))

<table>
<thead>
<tr>
<th>Domain</th>
<th>All Triads</th>
<th>High Performance</th>
<th>Moderate Performance</th>
<th>Low Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom Culture</td>
<td>3.3 (0.8)</td>
<td>4.0 (0.0)</td>
<td>3.3 (0.7)</td>
<td>2.6 (0.7)</td>
</tr>
<tr>
<td>Science Content</td>
<td>3.06 (0.8)</td>
<td>3.8 (0.4)</td>
<td>3.07 (0.8)</td>
<td>2.3 (0.7)</td>
</tr>
<tr>
<td>Use of Examples</td>
<td>3.05 (0.9)</td>
<td>3.6 (0.5)</td>
<td>3.1 (0.8)</td>
<td>2.3 (0.9)</td>
</tr>
<tr>
<td>Prior Knowledge</td>
<td>2.02 (1.0)</td>
<td>2.4 (1.2)</td>
<td>2.0 (0.9)</td>
<td>1.5 (0.5)</td>
</tr>
<tr>
<td>Use of Evidence</td>
<td>1.8 (1.1)</td>
<td>3.1 (0.8)</td>
<td>1.5 (0.8)</td>
<td>1.0 (0.0)</td>
</tr>
<tr>
<td>Sense Making</td>
<td>1.5 (0.7)</td>
<td>2.2 (0.7)</td>
<td>1.3 (0.5)</td>
<td>1.0 (0.0)</td>
</tr>
</tbody>
</table>

Triads were most highly rated on Classroom Culture and lowest on Sense Making. Use of Evidence and Sense Making were particularly low for the triads rated Low Performance and Moderate Performance. Figure 1 displays the relationships between level of performance effectiveness and domain rating.

![Figure 1. Mean AIM instructional domain score by performance category.](image)

One-way analysis of variance indicated the presence of significant differences between domain scores across performance categories, $F(17, 174) = 18.4, p < .0001$. Post hoc analysis with the Tukey HSD test indicated no significant differences occurred between the Classroom Culture, Science Content, and Use of Evidence domain scores. Further, no significant differences were observed between the Surface Prior Knowledge, Use of Evidence, and Sense Making domains. However, post hoc analysis with the Tukey HSD test did indicate that across all effectiveness categories, the Classroom Culture, Science Content, and Use of Evidence
domain scores were significantly higher than the Surface Prior Knowledge, Use of Evidence, and Sense Making domains.

Post hoc analysis further identified significant differences between domain scores across performance categories. Table 7 displays difference in domain scores between categories of team performance. Significant differences were observed on the Classroom Culture, Science Content, Use of Examples, and Use of Evidence domains.

Table 7. Instructional domain scores by team performance rating.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Performance Rating</th>
<th>Performance Rating</th>
<th>Mean Difference</th>
<th>p - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom Culture</td>
<td>High</td>
<td>Moderate</td>
<td>.70</td>
<td>.63</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>1.4</td>
<td>.01*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Low</td>
<td>.68</td>
<td>.75</td>
</tr>
<tr>
<td>Science Content</td>
<td>High</td>
<td>Moderate</td>
<td>.71</td>
<td>.61</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>1.5</td>
<td>.002*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Low</td>
<td>.82</td>
<td>.42</td>
</tr>
<tr>
<td>Use of Examples</td>
<td>High</td>
<td>Moderate</td>
<td>.42</td>
<td>.99</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>1.2</td>
<td>.04*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Low</td>
<td>.82</td>
<td>.41</td>
</tr>
<tr>
<td>Surface Prior Knowledge</td>
<td>High</td>
<td>Moderate</td>
<td>.41</td>
<td>.99</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>.94</td>
<td>.34</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Low</td>
<td>.53</td>
<td>.96</td>
</tr>
<tr>
<td>Use of Evidence</td>
<td>High</td>
<td>Moderate</td>
<td>1.6</td>
<td>&lt;.0001*</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>2.1</td>
<td>&lt;.0001*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Low</td>
<td>.46</td>
<td>.98</td>
</tr>
<tr>
<td>Sense Making</td>
<td>High</td>
<td>Moderate</td>
<td>.88</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>1.2</td>
<td>.04*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Low</td>
<td>.33</td>
<td>.99</td>
</tr>
</tbody>
</table>

Note. Significance level α = .05

Research Question 2: How was satisfaction with team lesson planning and implementation distributed across and within triads?

Table 8 displays the Team Satisfaction scores and ratings across triads. Overall, it is seen that triads were generally satisfied with the way their triad worked together to collaboratively
plan and teach lessons; of the 32 triads, 30 were Satisfied and 2 were Moderately Satisfied. No Dissatisfied triads were noted.

Table 8. Team satisfaction scores and ratings.

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Team Satisfaction Score ($S_{mean}$)</th>
<th>Team Satisfaction Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8.33</td>
<td>Satisfied</td>
</tr>
<tr>
<td>3</td>
<td>8.25</td>
<td>Satisfied</td>
</tr>
<tr>
<td>5</td>
<td>9.42</td>
<td>Satisfied</td>
</tr>
<tr>
<td>6</td>
<td>7.75</td>
<td>Satisfied</td>
</tr>
<tr>
<td>7</td>
<td>8.58</td>
<td>Satisfied</td>
</tr>
<tr>
<td>8</td>
<td>8.5</td>
<td>Satisfied</td>
</tr>
<tr>
<td>9</td>
<td>8.63</td>
<td>Satisfied</td>
</tr>
<tr>
<td>10</td>
<td>8.42</td>
<td>Satisfied</td>
</tr>
<tr>
<td>13</td>
<td>8.92</td>
<td>Satisfied</td>
</tr>
<tr>
<td>14</td>
<td>8.83</td>
<td>Satisfied</td>
</tr>
<tr>
<td>15</td>
<td>8.17</td>
<td>Satisfied</td>
</tr>
<tr>
<td>16</td>
<td>7.33</td>
<td>Satisfied</td>
</tr>
<tr>
<td>18</td>
<td>8.0</td>
<td>Satisfied</td>
</tr>
<tr>
<td>19</td>
<td>7.0</td>
<td>Satisfied</td>
</tr>
<tr>
<td>20</td>
<td>7.75</td>
<td>Satisfied</td>
</tr>
<tr>
<td>22</td>
<td>8.0</td>
<td>Satisfied</td>
</tr>
<tr>
<td>23</td>
<td>7.63</td>
<td>Satisfied</td>
</tr>
<tr>
<td>25</td>
<td>7.0</td>
<td>Satisfied</td>
</tr>
<tr>
<td>26</td>
<td>8.5</td>
<td>Satisfied</td>
</tr>
<tr>
<td>27</td>
<td>9.42</td>
<td>Satisfied</td>
</tr>
<tr>
<td>28</td>
<td>8.5</td>
<td>Satisfied</td>
</tr>
<tr>
<td>31</td>
<td>8.5</td>
<td>Satisfied</td>
</tr>
<tr>
<td>35</td>
<td>7.17</td>
<td>Satisfied</td>
</tr>
<tr>
<td>39</td>
<td>6.33</td>
<td>Moderately Satisfied</td>
</tr>
<tr>
<td>41</td>
<td>9.63</td>
<td>Satisfied</td>
</tr>
<tr>
<td>42</td>
<td>8.83</td>
<td>Satisfied</td>
</tr>
<tr>
<td>43</td>
<td>7.5</td>
<td>Satisfied</td>
</tr>
<tr>
<td>44</td>
<td>8.17</td>
<td>Satisfied</td>
</tr>
<tr>
<td>45</td>
<td>7.0</td>
<td>Satisfied</td>
</tr>
<tr>
<td>46</td>
<td>6.67</td>
<td>Moderately Satisfied</td>
</tr>
<tr>
<td>47</td>
<td>8.50</td>
<td>Satisfied</td>
</tr>
<tr>
<td>50</td>
<td>7.17</td>
<td>Satisfied</td>
</tr>
</tbody>
</table>

Operationalizing team satisfaction as the mean of all individual satisfaction ratings masks the specific characteristics of individual team members. To counteract this loss of information, Team Satisfaction Profiles were created for each triad. Team Satisfaction Profiles display the mean individual satisfaction ratings for each triad member. Table 9 displays the Team
Satisfaction Profiles; individual satisfaction ratings are presented in the order of cooperating teacher, engineering fellow, student teacher.

Table 9. Team satisfaction ratings and profiles.

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Team Satisfaction Rating</th>
<th>Team Satisfaction Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Satisfied</td>
<td>S, MS, S</td>
</tr>
<tr>
<td>3</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>5</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>6</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>7</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>8</td>
<td>Satisfied</td>
<td>S, MS, S</td>
</tr>
<tr>
<td>9</td>
<td>Satisfied</td>
<td>S, x, S</td>
</tr>
<tr>
<td>10</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>13</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>14</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>15</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>16</td>
<td>Satisfied</td>
<td>S, D, S</td>
</tr>
<tr>
<td>18</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>19</td>
<td>Satisfied</td>
<td>D, S, S</td>
</tr>
<tr>
<td>20</td>
<td>Satisfied</td>
<td>S, S, x</td>
</tr>
<tr>
<td>22</td>
<td>Satisfied</td>
<td>x, S, S</td>
</tr>
<tr>
<td>23</td>
<td>Satisfied</td>
<td>S, S, x</td>
</tr>
<tr>
<td>25</td>
<td>Satisfied</td>
<td>x, S, MS</td>
</tr>
<tr>
<td>26</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>27</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>28</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>31</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>35</td>
<td>Satisfied</td>
<td>MS, S, S</td>
</tr>
<tr>
<td>39</td>
<td>Moderately Satisfied</td>
<td>MS, MS, MS</td>
</tr>
<tr>
<td>41</td>
<td>Satisfied</td>
<td>x, S, S</td>
</tr>
<tr>
<td>42</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>43</td>
<td>Satisfied</td>
<td>S, S, D</td>
</tr>
<tr>
<td>44</td>
<td>Satisfied</td>
<td>S, S, S</td>
</tr>
<tr>
<td>45</td>
<td>Satisfied</td>
<td>S, S, D</td>
</tr>
<tr>
<td>46</td>
<td>Moderately Satisfied</td>
<td>MS, MS, MS</td>
</tr>
<tr>
<td>47</td>
<td>Satisfied</td>
<td>S, S, x</td>
</tr>
<tr>
<td>50</td>
<td>Satisfied</td>
<td>S, S, MS</td>
</tr>
</tbody>
</table>

Note. S = Satisfied, MS = Moderately satisfied, D = Dissatisfied, x = no response.

Individual satisfaction ratings were not homogeneous within triads. Of the 30 triads rated as Satisfied, eight had inhomogeneous Team Satisfaction Profiles. The inhomogeneity of Triad Satisfaction Profiles illustrates the drawback of operationalizing team-level satisfaction as means of individual satisfaction scores: triads rated Satisfied may contain Moderately Satisfied or
Dissatisfied members, while triads rated lower in satisfaction may have satisfied members. Of the 30 triads rated as Effective, five had two Satisfied members and one Moderately Satisfied member; three had two Satisfied members and one Dissatisfied member. The two Moderately Satisfied triads were homogeneously so; in these triads, all three members were Moderately Satisfied. No instances in which all three triad member satisfaction ratings differed were noted.

**Research Question 3: What levels of team effectiveness (performance + satisfaction) were achieved by the Trinect triads?**

Table 10 displays the Team Effectiveness ratings for the triads. Ten triads were rated as Effective, sixteen triads were rated as Moderately Effective, and six triads were rated Ineffective.

**Table 10. Triad team effectiveness ratings.**

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Team Performance Rating</th>
<th>Team Satisfaction Rating</th>
<th>Team Effectiveness Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Satisfied</td>
<td>Moderately Effective</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Satisfied</td>
<td>Moderately Effective</td>
</tr>
<tr>
<td>5</td>
<td>Moderate</td>
<td>Satisfied</td>
<td>Moderately Effective</td>
</tr>
<tr>
<td>6</td>
<td>High</td>
<td>Satisfied</td>
<td>Effective</td>
</tr>
<tr>
<td>7</td>
<td>Moderate</td>
<td>Satisfied</td>
<td>Moderately Effective</td>
</tr>
<tr>
<td>8</td>
<td>Low</td>
<td>Satisfied</td>
<td>Ineffective</td>
</tr>
<tr>
<td>9</td>
<td>Moderate</td>
<td>Satisfied</td>
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<tr>
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<td>Satisfied</td>
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<tr>
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<td>Satisfied</td>
<td>Moderately Effective</td>
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</tr>
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</tr>
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<td>Satisfied</td>
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</tr>
<tr>
<td>43</td>
<td>High</td>
<td>Satisfied</td>
<td>Effective</td>
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Table 10. (continued)

<table>
<thead>
<tr>
<th>Triad ID</th>
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<th>Team Satisfaction Rating</th>
<th>Team Effectiveness Rating</th>
</tr>
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<td>44</td>
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<tr>
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</tr>
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<td>46</td>
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</tr>
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<td>47</td>
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</tr>
<tr>
<td>50</td>
<td>High</td>
<td>Satisfied</td>
<td>Effective</td>
</tr>
</tbody>
</table>

Table 11 displays the Team Effectiveness ratings along with the Team Satisfaction Profiles. Discrepancies in individual satisfaction were not tightly associated with Team Effectiveness ratings. Discrepant satisfaction scores were observed in 2 effective triads, 3 moderately effective triads, and 3 ineffective triads. However, while discrepant perceptions of satisfaction may not have been tightly linked to team effectiveness ratings, the presence of discrepancies may be used to identify and diagnose problems within triads.

Table 11. Team effectiveness rating by team satisfaction profile.

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Team Effectiveness Rating</th>
<th>Team Satisfaction Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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</tr>
<tr>
<td>3</td>
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<td>S, S, S</td>
</tr>
<tr>
<td>5</td>
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<td>S, S, S</td>
</tr>
<tr>
<td>6</td>
<td>Effective</td>
<td>S, S, S</td>
</tr>
<tr>
<td>7</td>
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<td>S, S, S</td>
</tr>
<tr>
<td>8</td>
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<td>S, MS, S</td>
</tr>
<tr>
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<td>S, x, S</td>
</tr>
<tr>
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</tr>
<tr>
<td>13</td>
<td>Effective</td>
<td>S, S, S</td>
</tr>
<tr>
<td>14</td>
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<td>S, S, S</td>
</tr>
<tr>
<td>15</td>
<td>Effective</td>
<td>S, S, S</td>
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<td>27</td>
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<td>28</td>
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<td>31</td>
<td>Ineffective</td>
<td>S, S, S</td>
</tr>
<tr>
<td>35</td>
<td>Moderately Effective</td>
<td>MS, S, S</td>
</tr>
</tbody>
</table>
Table 11. (continued)

<table>
<thead>
<tr>
<th>Triad ID</th>
<th>Team Effectiveness Rating</th>
<th>Team Satisfaction Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
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<tr>
<td>41</td>
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<td>46</td>
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<td>MS, MS, MS</td>
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<tr>
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<td>Moderately Effective</td>
<td>S, S, x</td>
</tr>
<tr>
<td>50</td>
<td>Effective</td>
<td>S, S, MS</td>
</tr>
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</table>

**Discussion**

**Team Performance**

Across all levels of team effectiveness, triads were rated significantly higher on Classroom Culture, Science Content, and Engaging with Examples and Phenomena than Surface Prior Knowledge, Using Evidence to Draw Conclusions and Make Claims About Phenomena, and Sense Making of the Targeted Idea. Intriguingly, domain scores exhibited a similar pattern between the effective and ineffective triads, indicating that some domains continue to be challenging for all groups. Further, significant differences were noted between the effective and moderately effective triads and between the effective and ineffective triads. Effective triads scored significantly higher on Use of Evidence than did the moderately effective triads. Additional significant differences were observed between the effective and ineffective triads on Classroom Culture, Science Content, Use of Examples, Use of Evidence, and Sense Making. The Surface Prior Knowledge domain was the only area with no significant differences between effectiveness levels.

**Content, culture, and use of examples.** Triads were rated most highly on the Classroom Culture, Science Content, and Engaging with Examples and Phenomena domains. Classroom Culture reflects the extent to which triads created a learning environment supportive of positive
student science experiences and opportunities for learning; indicators of a supportive classroom environment include respect for the contributions of all students, high expectations of student learning, and collegial relationships between students. While this was the most highly rated domain for all triads, the effective triads scored higher on Classroom Culture than the moderately effective triads and significantly higher than the ineffective triads. Triad 22, rated as effective, received the highest rating on all sub-indicators of Classroom Culture, as did Triad 6, also rated as effective; these triads showed a high degree of respect for student ideas and maintained high expectations for student learning. While the moderately effective triads similarly upheld a positive classroom climate, their overall rating for this domain was lower than those for the effective triads. For instance, Triad 18, rated moderately effective, was rated low on Classroom Culture; this team maintained high expectations for student learning yet encountered difficulty keeping students engaged during a class discussion. Classroom Culture was the area in which the ineffective triads scored the highest; however, no ineffective triad received the highest rating within this domain. Thus, while a positive science learning environment was likely valued by all triads, the extent to which team members were able to create and maintain such an environment was higher in some triads than others. Student behavior issues, compounded by the relative inexperience of the student teachers and engineering fellows with respect to classroom management, may have contributed difficulties with Classroom Culture. Triads working in classrooms with a high incidence of disruptive students may encounter challenges related to Classroom Culture, and teachers who are inexperienced in classroom management may have difficulties meeting these challenges.

Science Content reflects the extent to which the content related to the triad’s targeted science idea was both accurate and developmentally appropriate and was the second most highly
rated domain across all effectiveness levels. Triads rated as effective were rated significantly higher on Science Content than the ineffective triads. Triad 31, rated as ineffective, presented content that was accurate but developmentally inappropriate. The student teacher in this triad presented a lesson targeting the formation of wind. During a post-lesson conversation with the observer, this student teacher proudly shared the numerous meteorological sources she used to ensure that lesson content was accurate. Although well-planned and accurate, lesson content centered on the relationship between the Earth’s rotation, the Coriolis force, and the formation of high and low pressure centers; students struggled to comprehend the lesson, and as a result, this triad’s objectives for the lesson were likely not met. Triad 8, rated ineffective, presented content that was inaccurate. In a lesson on the properties of solar system planets, this triad’s student teacher presented a misconception view; rather than identifying mass as the source of a planet’s gravitational attraction, planetary gravitation was presented as a function of a planet’s rotational speed. Triad 6, rated effective, implemented a science lesson centered on the nature of recycling. During the lesson, recycling was presented as simply the breaking down and reusing of materials; students were asked to brainstorm ways a given object could be reused or recycled. The recycling of materials is quite complex, but this triad presented recycling accurately while maintaining awareness of student capabilities. Differences between the approach to content were apparent between the effective and ineffective triads. Although planetary gravitational attraction may be introduced at a grade-appropriate level, the student teacher in Triad 8 presented a misconception view. Triad 31 presented content that was far too advanced for elementary students. Careful consideration of science standards and an appropriate understanding of how people learn could help triads recognize and avoid developmentally inappropriate content. Triad 6 chose to address a highly complex subject in a simple way, reflective of an awareness of
student ability levels. Interestingly, in both Effective Triad 6 and Ineffective Triad 31, lesson content was developed by student teachers. In the case of Triad 6, consultation with the team’s engineering fellow was evident, and may have reduced the risk of presentation of misconception views. The developmentally inappropriate content presented by Triad 31 was, for some reason, not filtered by that triad’s cooperating teacher. In any case, team effectiveness of co-teaching triads may thus be increased through attention to the accuracy and developmental appropriateness of science content, both of which likely require the input of all triad members.

Use of Examples and Phenomena refers to the opportunities provided to students to engage with examples of natural phenomena that were accessible and that targeted aspects of phenomena that were relevant to triad lesson objectives. Across all triads, Use of Examples and Phenomena received approximately the same mean rating as Science Content. Triads rated as effective were rated significantly higher on Use of Examples and Phenomena than the ineffective triads. Triad 41, rated as ineffective, implemented a lesson on force and motion; during the lesson, students observed the impact of adding mass to a car that is rolled down a track. While a car rolling down a track is an example that is accessible to students (e.g., playing with toys or on a playground slide), members of Triad 41 did not make clear to students the aspects of the cars’ motion on which they should focus. Thus, while Triad 41 presented an example that was likely accessible to students, they did not explicitly draw students’ attention to the aspects of the example relevant to their lesson objectives, which may lead to students playing with materials and missing the point of the lesson. Conversely, Effective Triad 50 presented a lesson on the effects of erosion, as depicted by use of a stream table; although living in an urban setting, many students are likely familiar with the erosive effect of water, and thus lesson content was readily accessible to students. In addition, students were asked to draw a “before and after” picture of
the stream table, thus focusing them on aspects of the phenomena relevant to the targeted idea. Both triads worked to engage students with accessible examples and phenomena, but the extent to which they focused students’ attention on the aspects of the examples and phenomena differed. Many of the triads participating in this study made use of commercially available science curriculum packages; such materials are often grade-level specific, thereby increasing the likelihood that the examples and phenomena presented to students are appropriately accessible. However, focusing students on relevant aspects of these phenomena may require a skillful approach, particularly in situations where materials must be adapted to district standards not directly targeted by the curriculum. In this case, triads must consider lesson objectives in light of the logical progression of the lesson to ensure that relevant aspects of examples and phenomena are not missed. The effective triads may have been more successful at discerning the relevant aspects of examples and phenomena than those rated ineffective or moderately effective.

**Use of prior knowledge, evidence, and sense-making practices.** Opportunities to Surface Prior Knowledge, Using Evidence to Draw Conclusions and Make Claims About Phenomena, and Sense Making of the Targeted Idea represent the second cluster of Team Performance indicators. Triad scores across these three items were significantly lower than those for Classroom Culture, Science Content, and Use of Examples. However, while their overall performance in these areas was lower, effective triads were rated significantly higher than the ineffective and moderately effective triads in all three domains. Given the importance of the Surface Prior Knowledge, Use of Evidence, and Sense Making domains with respect to what is known about how students learn science, these items warrant special attention.

Surfacing of student prior knowledge was difficult for all triads, and several did not present such opportunities at all. Indicators of sufficient opportunities to share and make use of
students’ prior knowledge include deliberately provided opportunities for students to become aware of and share prior knowledge and evidence of non-judgmental attitudes toward student prior knowledge. Solicitation and use of student prior knowledge is a crucial aspect of the knowledge-generation process in school science settings. Opportunities for students to share prior experiences with and knowledge of targeted science ideas relate directly to the conception of scientific knowledge as being socially constructed (Driver et al., 1994); in order to move student thinking toward the desired understanding of targeted concepts, teachers must first become aware of what prior knowledge of and experience with relevant science content students bring with them. However, the nature of the Surface Prior Knowledge domain indicator is inherently different than the Classroom Culture, Science Content, and Use of Examples and Phenomena domains. Considered together, the Science Content, Use of Examples, and Classroom Culture indicators represent aspects of science instruction that cannot be avoided; to teach science at even a minimally recognizable level requires some form of science content involving possibly irrelevant but certainly noticeable examples while occurring in some type of classroom culture. Surfacing students’ prior knowledge of and experience with science concepts, on the other hand, is an aspect of instruction that may seem unnecessary, may be forgotten, or may not be considered at all. Thus, while Science Content, Use of Examples, and Classroom Culture are unavoidable, surfacing students’ prior knowledge is just the opposite – science instructors can avoid soliciting students’ prior knowledge without either knowing or caring. This notion of “avoidable aspects of instruction” helps explain the low Surface Prior Knowledge ratings received by ineffective and moderately effective triads: some of these triads were not observed to solicit students’ prior ideas at all. While they may not have always done so effectively, all of the effective triads engaged in some level of surfacing of prior knowledge. In
This case, team effectiveness may have hindered not only by poor enactment of an instructional domain but its absence as well. Increasing the success of triads in this domain will likely require increased professional development emphasis on use of students’ prior knowledge and experience, particularly focusing on the importance of doing so (vis a vis theories of science learning), providing practical techniques triad members can use to gain access to student thinking, and conducting routine observations to ensure prior knowledge is being accessed and used appropriately.

Using evidence to draw conclusions and support and refute claims is a crucial aspect of science practice. The Use of Evidence to Draw Conclusions and Make Claims About Examples and Phenomena domain reflects the extent to which triads helped students understand and interpret data and use evidence to both support and refute claims. Effective triads were rated significantly higher on this domain than the ineffective and moderately effective triads.

Triad 42, rated as effective, asked students to draw conclusions about potential impacts on an ecosystem if elements of a food chain were removed; the triad’s use of evidence was highly likely to help students learn the targeted idea. Moderately Effective Triad 46, on the other hand, provided few opportunities for students to reason with data and evidence. In this lesson, when opportunities for students to support claims were presented, triad members often presented the claim and asked students to provide support; in these cases, students were more limited in reasoning with evidence. Similar to the Surface Prior Knowledge domain, Use of Evidence may represent an “avoidable aspect of instruction”. Unlike content, examples, and classroom culture, reasoning with evidence may be skipped by teachers who view it as unnecessary, may be unaware of it, or simply run out of time to enact it. Observations support this assertion; of the 32
triads participating in this study, 8 did not engage in use of evidence at all, and these triads were all rated ineffective or moderately effective.

Triads’ willingness and ability to engage students in reasoning with evidence may represent a further barrier to enhanced team effectiveness. As was the case with providing opportunities to surface student prior knowledge, the extent to which triads provided opportunities for students to use evidence to draw conclusions and support claims may be related to triad members’ understanding of how children learn science. Understanding of such knowledge among preservice elementary teachers is known to be limited (Madsen & Olson, 2005); misconceptions that difficult concepts are best taught by a “direct transmission” means of instruction is common, coupled with a view that the purpose of hands-on activities is solely for increased motivation. Further, university-level coursework frequently employs a single-subject, lecture approach based on the “direct transmission” model of teaching (Felder, Woods, Stice, & Rugarcia, 2000); unless provided with a set of pedagogical alternatives, the majority of instruction delivered by engineering fellows and even teachers may be of a similar nature (Smagorinsky & Barnes, 2014). Engaging students in reasoning with evidence requires that students gather and/or examine evidence, and have a teacher guide them through evidence-based reasoning. Elementary classroom activities may be hands-on, but whether they generate evidence that can be used in scientific reasoning is another matter. In addition, reasoning about evidence requires a high level of content knowledge from teachers. If they do not possess that content knowledge, they will struggle to lead students in reasoning that is directed toward appropriate science concepts.

The final instructional domain rated was Sense Making of the Targeted Idea. Indicators of effective opportunities to help students make sense of science concepts related to a targeted
idea were deliberately provided opportunities for students to make connections between what occurred during instruction and the targeted idea and to consider new knowledge of the targeted idea in light of what they already know. Across all effectiveness levels, Sense Making was the lowest rated domain. Across the ineffective triads, Sense Making was rated at the lowest level of implementation with a standard deviation of zero, indicating systemic difficulties with sense making of targeted ideas. Additionally, of the 32 triads observed in this study, 9 did not engage in any sense making related to their targeted idea; of these teams, 1 was rated effective, 6 were moderately effective, and 2 were rated ineffective.

Triad 6, rated as effective, engaged in sense making in a lesson related to recycling. Students took part in a hands-on activity during this lesson, and while the triad was able to relate the activity to subsequent instruction on the targeted idea, they did not make connections between the activity and previous knowledge of recycling. Moderately Effective Triad 14 presented a lesson on the nature of scientific work; although this triad did engage in sense making activities during a student discussion, they did so in a cursory manner and with limited number of students. Triad 44, rated ineffective, taught a lesson on magnetic forces in which they sought to emphasize the use models in science; however, although the triad stated several times that “scientists use models”, they did not make clear to students why scientific model-use is important, nor did they make connections between the materials the students were using (magnets and paperclips) and scientific models. Thus, while the rudiments of a sense-making discussion were present, without teacher guidance, students likely were not able to make sense of the targeted idea in a conceptually sound manner.

Engaging in sense making of targeted ideas was challenging for all triads. Similar to the Prior Knowledge and Use of Evidence domains, issues with learning theory may lie at the root of
triads’ difficulties with sense making. Science instructors that view science as simply a set of facts and vocabulary words to be memorized, or a set of activities to be completed may have difficulty understanding how sense making is prerequisite for student learning. Madsen and Olson (2005) found that preservice elementary teachers are likely to hold the view that science activities will teach students as long as teachers keep the students on task. In addition, despite their engagement with research activities that likely involve some level of knowledge construction, engineering fellows may not notice connections between their everyday work and classroom science teaching unless specifically made aware of such.

**Team Member Satisfaction**

Effective teams do more than perform at a high level; in addition to exemplary team performance, effective teams meet the employment-related socioemotional needs of team members and promote high levels of satisfaction with team functionality. Triad satisfaction profiles indicate the presence of possible “two against one” coalition formation within triads; in some cases, these discrepancies may have negatively impacted team performance. Careful consideration of the relationship between team member satisfaction and team performance is thus warranted.

Although the differences between triads on Team Satisfaction between levels of team effectiveness were not significant, the least satisfied members of ineffective triads rated themselves a full scale point lower than the effective and minimally effective triads. Perhaps not surprisingly, some of the lowest Team Satisfaction ratings were associated with the lowest ratings of Team Performance. These cases highlight triads in which substantial challenges may have existed with respect to team functionality.
Triad 8, for instance, rated ineffective, received the lowest science lesson evaluation rating. The Team Satisfaction Profile for this triad was S, MS, S. This team experienced difficulties related to lesson planning. Engineering Fellow 8 was asked to plan science lessons for all classrooms at her grade level, a task for which she felt unprepared. In addition, on her short-answer survey response to “On a scale of 1-10, how satisfied are you with the planning process that your triad employed?” Engineering Fellow 8 rated this question as ‘2’. In her open-ended response, she expressed the perception that her triad’s lesson planning processes were impaired because the student teacher was not participating: “Our planning didn't work well, because it was only me and the cooperating teacher planning.” In this team, the perception of impaired team planning was not unanimous. Student Teacher 8, for instance, wrote that “Our lessons were always well planned and effective.” Cooperating Teacher 8 similarly expressed positive sentiments regarding team planning processes. Intriguingly, the science lesson this team presented contained numerous content errors and misconceptions.

Triad 45, also rated ineffective, similarly experienced difficulties related to planning. Student Teacher 45 was the triad’s least satisfied member with respect to team planning and implementation, expressing particularly low levels of satisfaction with team planning; she responded to the two survey items related to satisfaction with team planning with a ‘2’ and a ‘1’. In her open-ended survey responses, Student Teacher 45 stated that her team “did not plan together and that “one person did all of the planning so none of the other people knew what we were doing”’. This statement indicates that deficiencies in team planning may have impacted lesson implementation. Although he did not rate the survey items related to satisfaction with team planning and lesson implementation as low as Student Teacher 45, Engineering Fellow 45 expressed similar sentiments with respect to team planning efforts. In his open-ended survey
responses, Engineering Fellow 45 wrote “School teacher [the cooperating teacher] did not participate in planning well” and “school teacher [cooperating teacher] likes to do things on the fly. Thank god we have some planning. At least student teacher and I were planning.” In this triad, the perception of a breakdown in team planning processes was not unanimous. Cooperating Teacher 45 stated that while it was not always easy to find time for the triad to plan together, “when we did plan together, it went very well”. Other statements from this triad’s engineering fellow and student teacher indicate that their cooperating teacher was not always a full participant in triad activities. For instance, Engineering Fellow 45 wrote “We can accomplish more with the support from the [cooperating] teacher.” Student Teacher 45 stated “I wish that we could've integrated science and engineering more into other subjects but the cooperating teacher needs to be on board with ‘sacrificing’ time for that.” Thus, while Cooperating Teacher 45 felt the triad was running smoothly, her teammates did not share this perception.

These cases highlight a potential weakness of the Trinect triad model. A subgroup is a subset of a larger group whose members share between them a unique characteristic not possessed by other group members (Carton, 2011). In the cases presented above, triad members were observed to form subgroups based on a shared perception of team planning efficacy. In Triad 8, Cooperating Teacher 8 and Student Teacher 8 formed a two-person subgroup and shared the view that team planning was functioning smoothly; in Triad 45, Engineering Fellow 45 and Student Teacher 45 formed a subgroup based on their shared perception that their cooperating teacher was not making equitable contributions to team planning efforts. In these cases, subgroup formation may have impacted team effectiveness. Triad 45 was considered ineffective due to its low team performance score. Had this team’s performance rating been higher, their
overall team effectiveness would have increased; however, Student Teacher 45’s statement that “none of the other people knew what we were doing” illustrates that this team’s inability to plan effectively may have been an obstacle to effective lesson implementation. In the case of Triad 8, had all team members made contributions to team planning, the erroneous content related to planetary gravitation may have noticed and corrected. Subgroup formation within work teams is a natural process (Carton, 2011), and subgroups are not a priori problematic. Caplow (1968) and Simmel (1950), however, observe that within three-person groups, the potential for team conflict related to subgroup formation may be enhanced.

**Implications**

This study has implications for the areas of research in co-teaching, preservice and inservice science teaching professional development, and organizational psychology.

Published literature on co-teaching provides little guidance on research methods related to co-teaching effectiveness. Co-teachers are known to value positive relationships with their co-teacher peers; work from organizational psychology indicates that the quality of relationships between members of groups may impact group performance (e.g., Li, Li, & Wang, 2009), and a similar effect may exist within co-teaching teams. However, the co-teaching literature lacks discussion of the impact of co-teacher performance vis a vis relationships with their co-teaching partners. This study addressed this issue through evaluation of triad-taught science lessons in coordination with team member satisfaction. An understanding of co-teacher relationships and satisfaction is important to ascertain early in the experience; instruments could be used to identify potential “hot spots” and address underlying problems before a situation worsens.

This study focused on co-teaching triads, about which little is known. Research on co-teaching pairs indicates that co-teachers value collaborative planning, and that limited
opportunities to engage in planning with co-teaching peers may be problematic. Triads in this study were identified as facing challenges related to collaborative planning; these issues may have negatively impacted triad effectiveness. Unlike other co-teaching research, the triads in this study were not composed of co-teaching peers; differences in expertise and power existed between triad members. Despite these differences, several triads were able to leverage the expertise of triad members to co-plan and co-teach highly-rated lessons. Those who did not frequently cited issues with planning and the inequitable effort contributed by one or more triad members.

Science teaching in elementary school classrooms has been a subject of perennial concern. Trinect was created to help address this issue by pairing engineering graduate students with cooperating/student teacher pairs. Triads participating in this study encountered many of the challenges observed in solo-taught science classrooms. Despite the presence of a STEM professional, triads had difficulty with solicitation of student prior knowledge, use of evidence, and sense making of targeted concepts. Inclusion of a professional engineer in an elementary school science classroom is not a panacea for the issues faced by both novice and veteran teachers of elementary science. Related to their experiences and expertise, engineering graduate students may bring with them expert content knowledge and pedagogical approaches not well-suited for teaching in elementary school classrooms. If placed with teachers who themselves are not aware of or do not enact research-based science education practices, improvement of science instruction will be difficult to achieve. Institutions considering the inclusion of STEM professionals in elementary science programs as a means to enhance students’ science experience should be aware that the difficulties present in primary school science are not simply a matter of science content; mitigating challenges related to solicitation of student prior knowledge, use of
evidence, and sense making is essential. For example, teachers are known to value professional development that centers on presenting new content or expansion of previously known content (Ball, 1996; Desimone, 2007; Garet et al., 2001). While acquisition and expansion of content knowledge is certainly an important aspect of teacher education, such knowledge is insufficient for effective science instruction. In particular, science content knowledge as a standalone focus of professional development does not sufficiently address how children learn science, including issues of misconceptions, developmental appropriateness, and the role of prior knowledge, evidence-based reasoning, and sense-making. By addressing these issues alongside science content, crucial aspects of science instruction, including use of student prior knowledge, use of evidence, and sense making, may be less likely to be overlooked or viewed as arbitrary elements to be included when time permits. Support for triads’ efforts during planning and implementation may also make the inclusion of overlooked domains more likely.

**Limitations and Further Research**

With respect to findings of this study, several limitations exist. Most notably, triad Team Performance ratings were based on only one observed science lesson; Team Performance ratings may have been higher or lower had different lessons been observed. Similarly, Team Satisfaction ratings may have differed had participants been presented with a different set of questions. Science lesson evaluations occurred throughout the semester, and not all were made at the same point in the semester; thus, some of the variability in Team Performance ratings may be related to the extent to which triads were comfortable working with each other and co-teaching together. Finally, team effectiveness levels were determined in part by team performance on a co-taught science lesson; however, triads also taught engineering lessons, and
it cannot be a priori assumed that effective science instruction would be replicated in lessons on engineering.

Findings from this study further inform what we know about co-teaching. With the introduction of the Next Generation Science Standards, engineering will become an increasingly important component of school science programs. In what ways may team effectiveness be characterized as they plan and teach engineering lessons? Second, as described in the organizational psychology literature, team effectiveness is known to be supported by a certain set of interpersonal and environmental factors; the factors that support positive co-teaching experiences have been similarly well-studied. What similarities and differences exist between the factors that support effective teams and those that support positive co-teaching outcomes? Finally, Li, Li, and Wang (2009) indicate that team satisfaction may be positively correlated with team satisfaction. To what extent does a similar effect exist in STEM co-teaching triads? Further research is needed in these areas as science instruction is expected to become increasingly multidisciplinary.

References


CHAPTER 5. CONCLUSIONS AND IMPLICATIONS

Major Findings from Each Study

The studies presented here were motivated by the goal of better understanding the performance and functionality of Trinect co-teaching triads to inform professional development efforts in elementary science and engineering education. The functional and conflict-power-status perspectives on small group research that were used in these studies provide insight into Trinect co-teaching triad functionality by investigating mechanisms that may amplify or degrade team effectiveness and the distribution of knowledge, social power, and experience among team members. Together, these studies begin to provide an understanding of how the educational and professional backgrounds of co-teachers interact in the context of the classroom. Results of each of these studies are summarized below.

Study 1. Organizational Aspects of Science and Engineering Co-teaching Triads: A Review and Synthesis of Literature

The purpose of this review was to create a conceptual framework through which to better understand the functionality of Trinect co-teaching triads. Empirical and theoretical results from foundational areas of co-teaching research and small group behavior were reviewed, compared, and synthesized. Trinect co-teaching triads exemplify the characteristics of work teams (Banker, Field, Schroeder, & Sinha, 1996); in particular, science and engineering co-teaching triads were classified as project teams (Sundstrom, McIntyre, Halfhill, & Richards, 2000). Trinect co-teaching triads engage in a variety of instructional tasks, including activities related to collaborative planning and implementation of lessons. Team task typologies provide a theoretical lens with which to understand team member effort and resource sharing during team task performance. Triad co-teaching was identified as a compensatory task (Barrick, Stewart,
Neubert, & Mount, 1999); compensatory tasks are those in which the strengths and weaknesses of team members compensate for one another to produce an overall mean level of team performance. Members of Trinect co-teaching triads represent a wide range of experience with teaching in elementary schools; areas in which one member is weak, such as classroom management, may be compensated by another triad member who is strong in that area. Factors that may impact the team effectiveness of Trinect co-teaching triads include country of origin, social power disparities related to member educational and professional background, and team member personality characteristics (French & Raven, 1958; Kramer, Bhave, & Johnson, 2014; OECD, 2009). While co-teaching triads have wide latitude to choose the content, materials, and activities they will use during their co-taught lessons, they are bound by school district science standards, available materials, time constraints, and the developmental capabilities of young science learners; in this sense, Trinect co-teaching triads may be considered semi-autonomous work teams (Banker et al., 1996). Triad team effectiveness may be enhanced through the formation and maintenance of shared cognitive representations of the co-teaching task; such representations may include mutual agreement regarding approaches to pedagogy, shared understanding of lesson content, objectives, and goals, and shared knowledge of educational technology.

**Study 2. Team Member Role Distribution in Science and Engineering Co-teaching Triads**

The process of role adoption within work teams helps ensure that team members know for which aspects of the team task they are responsible and which are the responsibilities of their teammates. Further, role adoption may facilitate the formation and maintenance of shared cognitive representations of the team task and environment. General triad member roles identified in this study were Experienced Teacher, Steward of Developmental Appropriateness,
STEM Content Resource, STEM Curriculum Developer, Novice Teacher, and Bringer of New Ideas. Role distribution within triads indicates that the knowledge and experience required to teach elementary science lessons was present within triads. Role distribution across participant groups was in overall correspondence with triad member identity: co-teachers took on roles related to teaching and students, student teachers held roles related to teaching, students and also their status as preservice teachers, and engineering fellows took on roles related to STEM content knowledge. During collaborative planning meetings, triad members took on the roles of Full Collaborator, Supporting Collaborator, and Observer; distribution of these roles did not align with triad member identity. During co-taught lessons, triad members played the roles of Lead Teacher, Supporting Teacher, or Classroom Teacher; the distribution of these roles was in overall alignment with triad member identity. In addition, during the co-taught lessons, triads unanimously adopted a “one teach/two assist” model of co-teaching. Role conflict related to science and engineering content knowledge was observed in two triads; it was speculated that misalignment of shared cognitive representations related to the role of teachers in elementary science education may have catalyzed role conflict in triads. While the student and cooperating teacher participant groups were extensively involved in teaching and planning lessons, the engineering fellows held largely supporting or assistant roles; the infrequency with which the engineering fellows took on pedagogically-oriented roles has implications for the possible future careers of the engineering fellows and for students experienced more limited interaction with science and engineering professionals than was the intent of the Trinect model.

**Study 3. Team Effectiveness of Science and Engineering Co-teaching Triads**

To be successful, work teams must successfully accomplish their collective tasks while maintaining a work atmosphere supportive of positive team member relationships and
satisfaction. The extent to which teams are able to accomplish these things is captured in the construct of team effectiveness. This study investigated the team effectiveness of 32 Trinect co-teaching triads; the team effectiveness measures used in this study were 1) team performance ratings of a triad taught science lesson and 2) ratings of team member satisfaction related to triad collaborative planning and lesson implementation. With respect to the ratings of the triad-taught science lesson, teams were considered to exhibit high performance effectiveness, moderate performance effectiveness, and low performance effectiveness. The distribution of team effectiveness ratings was among triads in this study was 10 effective triads, 16 moderately effective triads, and 6 ineffective triads. Significant differences in science lesson/team performance scores were identified between the three team effectiveness categories, F(2, 29) = 57.8, p < .001. Post hoc analysis showed that the effective triads scored significantly higher on the science lesson evaluation than either the moderately effective or ineffective triads; further, the moderately effective triads scored significantly higher than the ineffective triads. Across all effectiveness categories, significant differences in domain scores were identified between two groups of items: Classroom Culture, Use of Examples, and Science Content were rated significantly higher than Surface Prior Knowledge, Use of Evidence, and Sense Making domain indicators, F(17, 174) = 18.4, p < .0001. Results of this study indicate that triads at all levels encountered challenges related to soliciting student thinking, reasoning with evidence, and making sense of observations during triad-taught science lessons. The disparity between the Classroom Culture, Use of Examples, and Science Content domain indicators and the Surface Prior Knowledge, Use of Evidence, and Sense Making domain indicators between triads may have been influenced by an absence of the latter three lesson elements pursuant to an unfamiliarity with theories of learning as they relate to elementary school science education.
Further, the triads with disparities in satisfaction and lower ratings of team effectiveness may have been impacted by the presence of team members who were dissatisfied with team planning activities.

**Broader Implications of the Three Studies**

Considered together, these studies have implications for the areas of science and engineering teacher professional development and preservice science teacher preparation.

**STEM Professionals in Elementary School Classrooms**

The use of STEM professionals in K-12 classrooms is often encouraged because of the high level of content knowledge and experience they may bring to the learning environment; indeed, a central feature of the Trinect project was the placement of an engineering graduate student in an elementary school classroom with a traditional cooperating teacher/student teacher dyad. Upon cursory consideration, it may seem a reasonable assumption that access to a STEM professional will catalyze an enhancement of students’ STEM experiences while simultaneously promoting the professional growth of teachers interacting with that STEM professional; however, an important caveat is warranted. An important aspect of the Trinect program was preservice and inservice teacher professional growth in science and engineering education. As such, the inclusion of the engineering fellows in their elementary classrooms occurred under carefully monitored conditions. Engineering fellows attended a lengthy professional development workshop focused on research-based science and engineering education practices and participated in weekly seminar classes led by university science education faculty; cooperating and student teachers also received professional development support. Participants were further supported by regular contact with project research personnel. Even in these circumstances, however, the question “With respect to science and engineering instruction, what
happens when engineering graduate students work with preservice and inservice teachers in the context of elementary school science teaching?” may be answered as “It’s complicated.” While the inclusion of the engineering fellows was observed to positively influence certain aspects of teachers’ nature of engineering instruction (Pleasants, 2018), with respect to science instruction the impacts may be somewhat more complex. Triads participating in the Chapter 4 study encountered challenges similar in nature to those found in nation-wide studies of elementary science teachers (e.g., Banilower et al., 2013). Thus, even with the support of a university-led science education research program, some of the observed triads encountered difficulties in the implementation of effective science lessons. Instances in which STEM professionals work with teachers in an unmonitored environment may therefore be far less likely to achieve their goals. Institutions wishing to pair STEM professionals with elementary science programs must remain aware that even under supportive conditions, effective instruction may be difficult to realize.

Mechanisms of Professional Growth

Findings from research on GK-12 K-12 teacher – STEM graduate partnerships indicate that professional growth can occur for both teachers and teaching fellows. In particular, GK-12 classroom teachers self-reported gains in STEM content knowledge, while the teaching fellows were reported as increasing in instructional self-efficacy. However, the mechanisms through which professional growth occurred were not made clear in studies conducted on these programs.

In the Trinect project, the collaborative planning meetings discussed in Chapter 4 may provide insight into processes related to professional growth that occur in STEM professional – classroom teacher partnerships. Six triads were observed during collaborative planning meetings; during these meetings only two triads engaged in discussion related to science and engineering content, and during these times content discussions were limited in scope and depth.
While the concern that the observed planning meetings were few in number cannot be ignored, the likelihood that the limited nature of content discussion occurred solely by chance is small; more likely is that the limited nature of content discussion was a systemic property of triad collaborative meetings.

Further support for the notion of limited content growth may be found among the science lesson observations described in Chapter 3. Across all levels of team effectiveness, the Science Content domain indicator was rated relatively high, but triads did encounter difficulty ensuring that science content was both relevant and accurate. Thus, while the notion that high-level knowledge of a STEM discipline will *a priori* promote content knowledge growth in classroom teachers is intuitively appealing, the triads observed in these studies indicate that, in practice, this notion may be unfounded. Theories of learning make clear that acquisition of unfamiliar science content requires carefully crafted learning opportunities occurring over extended periods of time; observations of triad planning meetings indicate that in professional development programs such as Trinect, these conditions may be difficult to achieve.

Why triads may have had such limited conversations about science content is worthy of further consideration. One possibility is that with regard to science content, triads may have simply acquiesced to curriculum materials. The relatively high scores on the Science Content domain are consistent with those observed among teachers who are not involved in professional development projects (Olson et al., 2018). An explanation for this consistency is that curriculum materials define both the content to be learned and the depth at which that content is addressed. Thus, a lesson taught directly from the curriculum materials is likely to contain science content that is both accurate and developmentally appropriate. Thus, in some triads, teachers may have not felt a need to further explore the content presented in the curriculum as (a) they do not view
themselves as content experts, and/or (b) they trust that the presentation of content in curriculum is sufficient in all regards for the needs of their students. Similarly, the engineering fellows may not have considered themselves as fully knowledgeable of student capabilities and developmentally appropriate science content; thus, the engineering fellows as well may have deferred to the presumed expertise of science curriculum materials. As a result, rather than taking time during collaborative planning meetings to engage in content-related discussions, collaborative planning time may have been used to focus on other issues, such as planning co-teaching roles, working out lesson logistics, or procuring lesson materials. This notion may also help explain the difficulties encountered by triads in helping students make sense of lesson content and activities. In order to design and implement substantive sense-making experiences, teachers must understand content at a much higher level than what will be presented to students. Thus, deference to curriculum materials may limit triad content discussions, which in turn limits the extent to which rich and well-considered sense-making can occur.

Prior research on GK-12 graduate teaching fellows indicates that fellows improved in areas of science teaching self-efficacy and the ability to share STEM content information with non-science audiences (Gamse et al., 2010; Mitchell et al., 2003). Again, the mechanisms through which these gains occur are uncertain. The triads observed in Chapter 4 may provide insight into the processes that promote improvement in STEM professionals’ pedagogical abilities. Trinect triads were found to unanimously employ a “one teach/two assist” approach to co-teaching, with the student teachers being twice as likely to take on the role of Lead Teacher than the cooperating teachers and nearly eight times more likely to enact this role than the engineering fellows. While the limited number of observations of triad-taught lessons in this study raises the concern that the engineering fellows were acting as Lead Teacher at other times,
again the likelihood that the engineering fellows took on the role of Lead Teacher in one of six observations by chance is likely slim. More likely, the relative non-engagement of the engineering fellow with lead teacher duties may have been systemic. This observation may be partially explained by the inclusion of a student teacher in the triad. Student teacher are on the cusp of beginning their careers as professional educators. Participant student teachers may thus have taken on extensive lead teacher responsibilities in response to their identity as a preservice teacher and their interpretation of university student-teaching requirements, despite the wide latitude they were given to engage in science and engineering co-teaching. Thus, the relative non-engagement of the engineering fellows with lead teaching duties may have been an unforeseen consequence of the Trinect model. However, statements made during the participant interviews by several engineering fellows indicate that they often “took a backseat” with respect to instructional responsibilities. In these cases, the extent to which the engineering fellow gained experience teaching in elementary school classrooms by taking on the role of Lead Teacher may have been limited. While these results pertain to the triads observed in this study, this finding has a broader implication. Many STEM professionals, including the engineering fellows in this project, have had little or no experience teaching science in elementary school science settings. While some may embrace the role of lead teacher enthusiastically, others may be hesitant to enact this role. Institutions wishing to provide STEM professionals with experience teaching in unfamiliar settings must be aware that opportunities for professional growth may in some cases be limited by features of the program or personal preference. Considered together with the observation that content knowledge growth may be difficult to enact, the achievement of mutual professional growth of persons participating in teacher – STEM professional partnerships, while possible, likely requires planning and effort beyond what may be available in many programs.
Co-teaching as an Organizational Activity

The studies presented in this dissertation were informed by insights and findings from areas of organizational psychology and behavior. First, congruencies between findings from co-teaching research and the areas of small group dynamics and behavior exist. For instance, findings from team mental models research indicate that robust and accurate team mental models may be facilitated by team planning; research on co-teaching makes quite clear the value of collaborative planning for healthy co-teaching relationships. Results presented in Chapter 3 indicate that the triads that faced challenges related to collaborative planning may have encountered difficulties in implementing effective science lessons, and thus were more likely to be rated at lower levels of team effectiveness. Second, the theory of team mental models indicates the presence of teamwork-oriented shared understandings that contain information related to the task-specific abilities and personality characteristics of team members; co-teaching research indicates that co-teachers who make the effort to get to know their co-teaching partners may encounter improved co-teaching relationships. In Chapter 3, role conflict between cooperating teachers and engineering fellows may have been related to mismatched understandings regarding the role of teachers in elementary school science programs and the purposes and goals of elementary science education. Finally, the team effectiveness approach may be a useful diagnostic tool for evaluating the health of co-teaching teams. Disparities in team satisfaction profiles provided evidence of potential “hot spots” in which conflict between triad members may have occurred; low science lesson evaluation ratings may be used to identify areas of instruction in which co-teachers need to improve. Considered together, these results show that investigative and evaluative frameworks developed in organizational psychology are appropriate to use in educational settings.
Connections to Co-teaching Literature

Paired co-teaching has been extensively studied in a variety of settings; little, however, is known about the functioning of co-teaching triads. While findings from studies of paired co-teachers are not directly analogous to co-teaching triads, congruencies between these two approaches to co-teaching do exist. This section situates findings from the studies presented in this dissertation within the larger context of the co-teaching literature.

Student outcomes. While studies of paired co-teachers have been subject to methodological and reliability concerns (Kloo & Zigmond, 2008; Volonino & Zigmond, 2007), findings from research on students in co-taught classrooms indicate the co-teaching may be an effective service delivery model (e.g., Chang, 2014; Walther-Thomas, 1997). Human subjects requirements limit the extent to which the Trinect program could investigate student outcomes. However, it is anticipated that, if implemented in accordance with principles of effective co-teaching and science instruction, student benefits will be realized in classrooms in which Trinect triads are present.

Co-teaching is predicated on the notion that the reduction of the student-to-teacher ratio in co-taught classroom benefits students as a result of increased individualized attention from teachers; this ratio is further reduced in classrooms hosting Trinect triads. Triads observed in these studies frequently employed a “lead with assistants” approach to co-teaching. Although in this model only one triad member acts as Lead Teacher, individuals acting as Supporting Teachers and Classroom Assistants may assist students individually and provide classroom management support, thus increasing the amount of individual attention students may receive and limiting the amount of lesson time spent managing student disruptions. Co-teaching models that pair co-teachers with small groups of students (e.g., station teaching, parallel teaching)
further reduce student-to-teacher ratios while acting as an effective medium for hands on STEM lessons (Forbes & Billet, 2012; Moorehead & Grillo, 2013).

A second rationale for co-teaching as an instructional strategy is the potential for synergistic interactions between co-teachers’ individual skillsets that create a rich learning environment not attainable by a single teacher; this amalgamation of distributed expertise is a key feature of the Trinect program. Elementary preservice and inservice teachers are frequently unprepared to teach engineering (Banilower et al., 2013). However, with careful planning and implementation that takes into account student capabilities, the knowledge, skill, and experience brought by the engineering fellows may provide many benefits for students in terms of science and engineering learning, both in terms of academic performance and, less tangibly, understanding of the natures of both science and engineering.

Trinect co-teaching triads thus exemplify the literature-based rationales for co-teaching. Through a reduction of the student-to-teacher ratio and thoughtful integration of the knowledge and skill of a STEM professional, the Trinect model has the potential to realize many of the benefits of co-teaching reported in the literature.

**Factors supportive of positive co-teaching outcomes.** Fundamental differences exist between pairs of co-teachers and co-teaching triads; thus, the research identified factors and conditions that support positive co-teaching outcomes for co-teaching pairs are not necessarily generalizable to co-teaching triads. While the studies presented in this dissertation did not directly assess such factors, observations and findings from these studies allow for consideration as to how these factors might function in Trinect triads. Considered below will be the ability to engage in efficient collaborative planning, personal and professional compatibility, and balanced parity relationships.
Collaborative planning. Findings from research on paired co-teachers makes clear that co-teachers highly value their ability to engage in effective and efficient collaborative planning (Bacharach, Heck, & Dahlberg, 2008; Friend, Cook, Hurley-Chamberlin, & Shamberger, 2010; Kohler-Evans, 2006); observations of triads during collaborative planning meetings indicate that while triads valued their collaborative planning meetings, inefficient use of time during planning meetings may be problematic in terms of lesson logistics and delivery of accurate science content. While triads likely value their ability to engage in collaborative planning, care must be taken to ensure that all members participate productively and that lesson roles and responsibilities are assigned and understood.

Personal and professional compatibility. Studies of paired co-teachers indicate that co-teachers place a high value on positive personal and professional relationships with their co-teaching partners (Mastropieri et al., 2005; Pratt, 2014; Rice & Zigmond, 2000). Triads observed during their collaborative planning meetings generally exhibited positive interpersonal interactions, and it is likely that such interactions laid the foundation that allowed triad members to work together harmoniously. Further, participants in the Chapter 4 study were generally satisfied with their triad’s collaborative planning routines and effectiveness; as collaborative planning requires a high degree of interpersonal interaction, it is likely that members of these triads experienced positive relationships with their teammates as well. Further, the Chapter 3 study describes role conflict in Triads A and F. Although these conflicts did not degenerate into open enmity, the differences in triad members’ professional and educational backgrounds may result in misaligned understanding of team member roles that may degrade triad effectiveness. Similar to findings from research on paired co-teachers, then, professional compatibility is likely a key ingredient of triad viability. Thus, in parallel with findings from studies of paired co-
teachers, it is likely that both personal and professional compatibility are factors that are crucial for triad success.

*Balanced parity relationships.* Parity in co-teaching relationships refers to the extent to which co-teachers are perceived as equals, both by their students and by their co-teaching peers. Observations presented in the Chapter 3 study indicate that balanced parity relationships were generally maintained within participating triads, with exceptions occurring in Triad E. Engineering Fellow E was observed to be actively excluded from his triad’s planning meeting by Student Teacher E, who summarily dismissed the ideas he brought to the team; during this triad’s co-taught lesson, Cooperating Teacher E sent signals to the class that Engineering Fellow E was not a fully functioning member of the triad. While no outward signs of conflict or enmity were observed in this triad, it is possible that this unbalanced parity relationship limited Engineering Fellow E’s professional growth and degraded his overall experience with the program. Balanced parity relationships help paired co-teachers feel valued by their students and by their peers, and it is likely that such relationships function similarly in co-teaching triads.

*Co-teaching roles and responsibilities.* Clarity of roles and responsibilities in co-teaching relationships helps ensure that co-teachers understand what they are to do during a co-taught lesson and increases the likelihood that all desired aspects of instruction will occur. Work by Bledsoe et al. (2004) indicates the roles taken on by members of GK-12 classroom teacher-graduate STEM fellow partnerships align with individual knowledge and skill. A similar designation of roles occurred among the triads participating in the Chapter 3 study: cooperating and student teachers more frequently identified with roles related to pedagogy and students, while the engineering fellows played roles related to science and engineering content. However, the roles with which triad members were identified were not always in congruence with their
observed actions during collaborative planning and lesson implementation. For example, while engineering fellows unanimously viewed themselves as content experts, content was rarely discussed in planning, and triads appeared to acquiesce to instructional materials to define the content and the depth to which it would be taught. Other roles, such as “Expert Teacher” were identified by most cooperating teachers and some student teachers, but the lack of sense-making, use of prior knowledge, and use of evidence to make claims indicates that expertise in science teaching had substantial room for growth. If those who identified themselves as “Expert Teacher” asserted this expertise in planning while lacking critical knowledge of those domains, it may have undermined the quality of the lesson. Triad members enacting roles in alignment with individual strength would inherently work to benefit the team, but accurate assessment of individual strengths and weaknesses is crucial for this to occur. In particular, triads should be moved toward an awareness that “direct instruction” style lessons that focus solely on activities, to the detriment of meaning-making activities, are not congruent with research-based practices for effective science instruction. Triad members may have conceptions of science learning that may not be accurate, and thus a conceptual change approach is needed to move triads toward integration of practices that more soundly support effective science instruction.

**Recommendations for Future Triads**

Based on the observations and findings presented in this dissertation, presented here are a set of four recommendations whose implementation may (a) enhance the degree of success achieved by future Trinect triads and (b) help guide those working on professional development projects that are similar in nature to Trinect. These recommendations are (1) work to ensure shared understandings of team member roles; (2) work to implement models of co-teaching more
complex that “lead with assistants”; (3) emphasize meaning making in science and engineering lessons; (4) focus on effective management of lesson time.

**Shared Understanding of Team Member Roles**

Findings from team mental models research indicate that team effectiveness is enhanced when team members possess among themselves a shared understanding of the team task and its associated goals and objectives (e.g., Mathieu et al., 2008; Stout et al., 1999). These findings are congruent with research on co-teaching dyads; co-teachers are more likely to be successful when both teachers are “on the same page” with respect to desired lesson outcomes and who is responsible for particular instructional tasks (Bouck, 2007). Further, triads observed in this study encountered challenges related to discrepant understandings of team member roles and lesson logistics. Thus, a first recommendation for future Trinect participants is to work to ensure that mutual understandings exist with respect to (1) general team member roles and (2) specific lesson roles and responsibilities.

Conflict related to misaligned understandings of triad member roles was observed in two of the triads participating in the Chapter 3 study. While these conflicts were limited in scope and did not deteriorate into open enmity, given the unique composition of Trinect co-teaching triads, the potential for deleterious role-related conflict is quite real. For instance, the educational environment in which many engineering graduate students receive their post-secondary education may rely heavily on a single subject, direct instruction approach; lacking readily-available pedagogical alternatives, engineering fellows may approach elementary science instruction in a similar way. On the other hand, the cooperating and student teachers may adopt a more student-centered, pedagogical approach. Unless disparities in understandings of the role of the teacher and content knowledge in elementary science education are identified and
discussed, role conflict may result. Additionally, cooperating teachers may sometimes feel reluctant to cede control of their classrooms to co-teaching partners; in particular, cooperating teachers may be hesitant to share lesson planning and lead teacher responsibilities. However, in order to promote the mutual professional growth of all triad members, it is critical that all triad members are able to substantively engage in all three aspects of the co-teaching process (co-planning, co-instruction, and co-assessment). Thus, while cooperating teachers may be perceived, by themselves and their teammates, as embodying the role of Experienced Teacher, cooperating teachers are encouraged to approach expression of this role as a mentor, and share responsibility, despite their years of experience with solo teaching.

Further conflict related to discrepant understandings of team member roles may occur with respect to the student teachers. Student teachers are in their final semester of an undergraduate degree and licensure program, and as such may feel pressure to adopt the role of Lead Teacher as often as possible, including during triad-taught lessons. While such a perspective is understandable, it may lead to tension within triads and uncertainty of roles with respect to the other triad members. Triads are thus encouraged to discuss ahead of time the role of the student teacher *vis a vis* the role of Lead Teacher and work to arrive at shared understandings of how roles and responsibilities will be apportioned. Interestingly, in this study, triads adopted a “lead with assistants” approach to co-teaching, despite being provided additional co-teaching models and being encouraged to experiment with and develop new triadic co-teaching models. When making decisions regarding individuals’ roles during collaborative planning and teaching, triads may need more support in choosing co-teaching models that more effectively distribute lead teacher responsibilities (e.g., station teaching, parallel teaching).
Triad co-teaching is a complex task occurring in a dynamic environment. As such, during co-implementation of lessons, it is critical that all team members are aware of their responsibilities during a co-taught lesson and that lesson logistics, demonstrations, and activities are well-rehearsed. An example of what may occur when lesson logistics are *not* well-rehearsed was observed in Triad D. Triad D’s co-taught lesson was an engineering activity focused on the design and building of “hand pollinators”. During this team’s planning session, although team members worked hard to find the required materials and discussed how students might use them, they did not make clear how or when materials would be distributed. As a result, Student Teacher D began to distribute materials during Engineering Fellow D’s class discussion, which resulted in derailment of the lesson. Had this triad ahead of time decided when materials would be distributed, this situation may have been avoided. In addition, Student Teacher D was not observed to have any other role during the lesson other than to distribute materials; this likely resulted in her using lesson time for other tasks and a concomitant lack of careful attention to Engineering Fellow D’s lead teaching. Thus, assignment or adoption of lesson roles and responsibilities and, when necessary, rehearsal of lesson roles, helps to ensure that lesson elements are neither repeated nor forgotten, and that triad members are using their expertise during planning as well as implementation of lessons. Thus, it is recommended that during triad planning meetings, care is taken to ensure that team members are made explicitly aware of both their own lesson roles and responsibilities and those of their teammates. A strength of a team-based approach to teaching is the presence of multiple adults in a single classroom, and working to arrive at a shared understanding of team member roles and responsibilities will help ensure that potential benefits are realized.
Expanded Repertoire of Co-teaching Models

Findings from GK-12 programs indicate that the classroom teacher – STEM professional model may be a medium for participant professional growth. Studies have shown that classroom teachers in these programs have heightened perceptions of science teaching self-efficacy and increased use of and fluency with inquiry teaching, while graduate teaching fellows have improved in areas of pedagogical skill and self-efficacy and communication with non-scientist audiences. The Trinect project has similar goals: through collaboration with an engineering graduate student, cooperating and student teachers may improve their science and engineering education skills, while the engineering fellows may experience increased comfort teaching young students and encounter an increased appreciation for the complexities of teaching and learning. However, observations of triad planning meetings and co-taught lessons indicate that the opportunities to realize potential growth in areas of pedagogical skill and self-efficacy and science and engineering content knowledge were limited, likely due to the limited role played by the engineering fellows during instruction as well as planning. Thus, a second recommendation for future triads is to maintain a focus on mutual professional growth through use of a diversity of co-teaching models and explicit awareness of ways that these roles can be used to promote mutual growth.

Triads observed for the Chapter 3 study unanimously employed a “one teach/two assist” approach to co-teaching; in this model, one triad member performed the role of Lead Teacher while their teammates acted in supportive or assistant roles. This finding parallels observations of paired co-teachers, who frequently adopt a “one teach/one assist” approach (Weiss & Lloyd, 2002). While a “lead with assistants” approach may be useful for modeling pedagogical strategies or techniques or in situations where one co-teacher does not possess content
knowledge adequate for the lesson, this model may result in an imbalance in perceptions of teacher authority, a less than optimal utilization of individual knowledge, skill, and experience, and unrealized opportunities for professional growth. Thus, while in certain circumstances a “lead with assistants” approach may be useful, future triads are encouraged to expand their repertoire of co-teaching models and work to implement those that allow for a more equal sharing of lead teacher responsibilities. The five models described by Cook and Friend (1995), for instance, may be easily adapted for use by co-teaching triads. Station and parallel teaching, for example, each place a single teacher with a subset of students, and may be useful when teaching complex content or engaging in hands-on activities (Moorehead & Grillo, 2013); working with a reduced number of students may also be helpful for engineering fellows who have yet to “gain their sea legs” in the classroom. Team teaching, in which all three triad members simultaneously share the lead teacher role, offers lead teaching experience along with the knowledge that one’s teammates are there to “save” them if things go awry or if instructions or content are presented inaccurately. Thus, while “one teach/two assist” may be the most easily implemented co-teaching model, overreliance on this approach limits the professional growth of those members who are not directly acting as a lead teacher. Adaptation or creation of more complex models of co-teaching can offer each triad member teaching experience commensurate with their experience, while the reduced student-to-teacher ratio in these models will be of benefit to students.

**Emphasize Meaning Making**

Across all levels of team effectiveness, triads participating in the Chapter 4 study performed significantly higher on the Science Content, Use of Examples, and Classroom Culture domains than the Surfacing Prior Knowledge, Use of Evidence, and Sense Making items. Taken
together, the second set of instructional domains represent “meaning making” with respect to science learning and are in harmony with what is known about how students learn science. Effective use of these aspects of science instruction may increase student comprehension of science lesson content and help ensure that triad learning goals are met. Thus, it is recommended that triads work to include explicit opportunities to solicit student prior knowledge of lesson concepts, use evidence in supporting and critiquing claims, and engage students in sense-making discussions that synthesize lesson content in support of targeted ideas.

Surfacing student’s prior knowledge and using that information to meaningfully guide instruction requires that teachers deeply understand how students learn and the important role played by prior knowledge in sense-making (including the tendency to develop misconceptions). “Direct instruction” approaches to science teaching assume that content is transmitted intact from teacher to students; the manner in which students understand lesson content will then necessarily be the same as the way in which that material is understood by the teacher. Decades of work, however, including that by Driver et al. (1994), have noted that science concepts are not learned “intact” via direct transfer from teacher to student. Instead, science learning involves substantial cognitive effort that often requires accommodation and conceptual change rather than simply adding additional concepts onto those previously known. Young students’ science understanding is often fraught with intuitive misconceptions that make difficult the acquisition of new and accurate science ideas. Thus, for conceptual change to occur, students and teachers must be aware of their prior knowledge, and new conceptions that are intelligible, plausible, and fruitful must be made available (Posner, Strike, Hewson, & Gertzog, 1982). Intelligibility, plausibility, and fruitfulness require that students are working with evidence and examining claims while working toward understanding of a new science idea. Therefore, triads that do not engage in
solicitation of students’ prior knowledge and experience are missing a crucial first step in the learning process – it is difficult to authentically move students toward a desired lesson outcome without explicit knowledge of what understandings they bring with them and how these ideas will impact their learning. Triads need to include in their lesson plans explicit opportunities for students to share their prior knowledge and experience with targeted science concepts. This may be accomplished by asking overt, open-ended questions about students’ knowledge and experience; in order that these questions are not overlooked, it is recommended that triads write these questions down in lesson plans and explicitly assign one or more members to ask the questions. In keeping with the Classroom Culture domain, student prior knowledge should be listened to and accepted non-judgmentally.

Using evidence to support and critique claims requires that students gather or have evidence available for analysis, and that teachers know how to help students reason through claims about the evidence. Teachers’ science content knowledge has long been an area of concern (e.g., Banilower et al., 2013), and this is prerequisite for leading evidence-based discussions about claims, as well as leading sense-making discussions about targeted science ideas. Sense-making of targeted ideas assists students in meaning-making by synthesizing lesson content and connecting new ideas to what they already know. Across all triads, sense-making was the domain on which triads were rated lowest, with several triads not engaging in sense-making at all. Opportunities for sense-making of targeted ideas may be undertaken at various points in a lesson, and may be used to help students understand portions of a lesson, an entire lesson, or as a vehicle for synthesizing content from several lessons. In each case, triads may optimize opportunities for sense-making by using explicitly written questions and discussion prompts that have been written into lesson plans and assigned to one or more triad members.
Meaning-making may also occur during engineering lessons. A popular lesson format in elementary engineering education is “plan-build-test”; this model engages students in a hands-on engineering design activity that is often centered on finding an optimum solution to a problem. During these activities, students consider the problem, plan how they will solve it using the available materials, and then build and test their design. Observations of engineering lessons show that while ample time is devoted to the planning, building, and testing of designs, triads often allow little time for meaning-making with respect to the activity. In the context of a “plan-build-test” activity, opportunities for meaning-making include discussing how student designs solved the problem, why designs did or did not perform as expected, and nature of engineering concepts such as optimization, the need for trade-offs, and the role of science and mathematics in engineering. Engineering in elementary schools is a relatively new phenomenon, and many elementary school teachers are unprepared to teach engineering; triads will need to integrate the knowledge, skill, and experience of their engineering fellows as the work to make meaning of engineering lessons and activities.

Working with teachers to engage students in meaning-making activities has been a perennial concern for science teacher educators, and while the recommendations made here regarding triads’ engagement in meaning-making may appear simplistic, their practical accomplishment will require a great deal more effort than simply asking them to do certain things in professional development workshops. Past Trinect professional development workshops have emphasized the integration of meaning-making activities into triad lessons, and while a limited amount of success has been achieved, substantive and enduring results have yet to be realized. The amount of time required for professional development that results in durable change is not available within the confines of a 16-week semester (e.g., Madsen & Olson, 2005;
Olson, Bruxvoort, & Vande Haar, 2016); instead, rather than relying on professional
development to do the “heavy lifting” required for teacher conceptual change, what is a needed is
a fundamental reimagining of university-level science content preparation and the role of
elementary teachers as subject generalists.

First, using evidence to support and critique scientific claims and engage in sense-making
activities requires that students gather and have available evidence for analysis and that teachers
know how to help students reason through claims about that evidence. For teachers to
effectively do so, they must first possess a robust conceptual understanding of the content to be
taught at a level more advanced than what will be presented to students. Problematically,
however, elementary teachers’ science content knowledge is often limited (Banilower et al.,
2013), thus posing a serious obstacle to effective meaning-making in the classroom. While it
may be tempting for programs interested in improving elementary teachers’ science content
understanding to simply require prospective teachers to “take more science”, it is noted here that
the content-related issues faced by elementary science teachers more often relate to the quality of
teachers’ understanding of science concepts rather than the quantity of science knowledge they
possess; simply adding additional content knowledge to what it already known, without a
concomitant examination of how that knowledge comes to be learned and the means to promote
these processes within students, will serve only to perpetuate the problem. The accomplishment
of such a task will likely require a fundamental restructuring of teacher education science content
programs. University science courses are often notorious centers of “stand and deliver” direct
instruction, and despite the best efforts of science teacher educators, elementary teachers may
adopt similar pedagogical approaches, including limited engagement in meaning-making
activities, in their own classrooms. A remedy for this issue is a wholesale shift of responsibility
for pre-service elementary science teacher content instruction out of university science
departments and into science education programs. Science education graduate students and
faculty members are required to be experienced science teachers that have completed graduate-
level science content work; these instructors would be highly capable of teaching pre-service
content courses with a concomitant focus on pedagogical content knowledge and learning theory.
Teaching science content alongside from the perspective of student learning shifts the conceptual
emphasis from content knowledge as a store of facts that can be transmitted intact to content
knowledge as set of understandings that have been carefully constructed using logic, evidence,
and student – teacher dialog; teachers who understand the knowledge construction process for
themselves will be more likely to conceptualize the difficulties students have in understanding
new science concepts, therefore increasing the likelihood that they will work to engage in
substantive meaning-making in a durable way.

As described previously, an observed disparity was present between the roles that the
engineering fellows were perceived to play and their observed actions during collaborative
planning and lesson implementation; in particular, engineering fellows were widely perceived to
act as STEM content resources, despite the fact that their actions within their triads did not
support such a notion. While the engineering fellows possess a large amount of advanced
science content knowledge, it is not necessarily organized in such a way as to support meaning-
making activities in elementary science classrooms; despite their status as “content experts”, the
engineering fellows are therefore not able to make up for the limited content understanding of
their preservice and inservice teacher teammates. Thus, a science content course taught by
science education faculty or graduate students would also be of benefit to the engineering
fellows; while their schedules may not permit participation in a full-time course, science content
relevant to the districts’ STEM goals may be covered during their weekly professional development seminars.

A second means of restructuring university teacher educations to accommodate improvement in meaning-making activities represents a “nuclear option” with respect to the roles of elementary teachers in science education. Rather than acting as subject generalists who teach the gamut of academic subjects, elementary schools might instead adopt the “subject specialist” approach used in middle and secondary schools; instead of a single teacher teaching science, mathematics, literacy, and social studies, for instance, elementary schools would then have dedicated content teachers that would focus on a single subject. Such an approach would allow teachers to be prepared in teacher education programs whose methods and focus mirror those used in secondary education programs; in particular, prospective elementary science teachers would be given the opportunity for in-depth study of science content and the nature of science, the conceptual foundations of science learning, and the means to manifest these understandings in the classroom through the use of research-based best practices. This model is currently in use for “specials” classes (e.g., art, music, physical education), and while adoption of this approach would require a radical reorganization of teacher education programs, the benefits in terms of teacher quality and student learning should far outweigh any bureaucratic headaches encountered along this “road to recovery”.

Time Management

Chapter 4 identified two sets of instructional domains. “Unavoidable” aspects of instruction were elements of science education that, of necessity, were present in all observed science lessons, while “avoidable” aspects were instructional elements that triads could, for a variety of reasons, include or not include while still making the case that they were teaching
science. In particular, triads frequently did not engage in sense-making activities due to running out of lesson time. Thus, while availability of time has been a perennial concern among educators at all levels, triads are encouraged to ensure that time is made available for sense-making activities.

Opportunities for making sense of lesson content often occur at the end of a lesson, at which point concerns regarding the availability of time are often at their highest. Failing to engage in sense-making activities due to time constraints is exemplified in the observed lesson for Triad C in the Chapter 3 study. Triad C taught a well-planned lesson designed to provide students with evidence that air has mass. Cooperating Teacher C and Student Teacher C rehearsed lesson activities and pacing during their observed planning meeting, and Engineering Fellow C had established how she would assist her teammates as they taught the lesson. The lesson unfolded as planned, and after all measurements had been made, the triad moved into a sense-making discussion during which they would use the data they had collected to provide evidence that air has mass. However, at a crucial moment in the discussion, Cooperating Teacher C notice that they were short on time; rather than continuing the logic flow leading to the conclusion that air has mass, she simply told the class “what [they] should write down” and skipped several intermediate pieces of the argument. During the discussion, several students had questions about the activity that were therefore not answered, and for these students, it is unlikely that being told the outcome carried the conceptual weight of working the result out for themselves. In this case, time management problems limited the effectiveness of Triad C’s lesson.

Engineering activities represent an additional area in which time management is crucial. Triads implementing “plan-build-test” activities must closely monitor time to ensure that
adequate time is available for meaning-making activities such as discussion of engineering strategies used by students, degree of observed success of built items, and how classroom work relates to the practices of “real” engineers. Students do not learn from hands-on activities alone, but rather require the guidance of teachers to help them connect activities to desired learning goals. Failure to engage in meaning-making during engineering lessons may create or reinforce student (and possibly teacher) misconceptions about the nature of engineering and leave students unsure about what they were to have learned during a lesson.

Effective management of time during lessons may be challenging for teachers at all levels of experience, and Trinect triads are certainly not exceptions to this rule. However, in order for triads to maximize lesson effectiveness and ensure learning goals and objectives are met, it is crucial that they find ways to manage time such that opportunities to synthesize and review lesson material and connect activities to larger concepts are not left out or skipped. Elementary science teaching is often dynamic and complex, and it can be difficult to anticipate all possible contingencies. However, co-teaching is predicated on the potential benefits of a reduced student-to-teacher ratio, and with three adults present in a single classroom, triads are encouraged to find ways to work with emergent issues while still maintaining the flow of the lesson. Additionally, triads may observe the amount of time taken by students to complete specific tasks (e.g., planning for an engineered product) and use these observations to help prepare for future lessons. Time management is an important aspect of effective elementary science and engineering education; it is recommended that triads utilize their unique composition to find creative ways to ensure time is used efficiently such that opportunities for meaning-making are made available.
Closing Remarks

While the discussion presented here has been somewhat skeptical of the efficacy of pairing STEM professionals with classroom teachers as an efficacious medium for professional growth, a strong caveat is warranted. The conclusion that enhancement of science and engineering education through collaboration between STEM professionals and classroom teachers may be difficult to achieve is not intended to be reflective of the efforts and intentions of participants in such programs, nor a call to end such efforts. Instead, the field must acknowledge that effective science teaching at the elementary level is extremely difficult. Elementary teachers are prepared as subject generalists and thus do not have space in their teacher education programs for in-depth studies of science content. Further, professional development programs that allow inservice teachers to improve their content understandings are rare (Banilower et al. 2013). When engineering is expected to be integrated into elementary science programs, it is not surprising that challenges will emerge, as elementary teachers have even less preparation in engineering than in science (Banilower et al., 2013). Therefore, while the triads in this study struggled with sense-making, sometimes taught inaccurate or developmentally inappropriate content, and did not utilize their engineering fellows in ways that had been anticipated, for the most part they were able to reach moderate to high levels of effectiveness, engage students with STEM professionals, and support student and cooperating teachers. Institutions wishing to undertake STEM professional – classroom teacher partnerships should carefully consider both the benefits and perils of this approach, recognizing the high level of complexity present in elementary science and engineering education, the complex dynamics of teams, and searching for ways to promote equitable and appropriate role definition such that opportunities for both teacher and student learning are maximized.
References


APPENDIX 1. SYNOPSES OF TRIAD MEMBER INTERACTIONS

This study collected data from 7 triads during the Fall 2017 semester. Synopses of triad member relational characteristics are presented here.

Triad A

Triad A was composed of a female cooperating teacher, a female engineering fellow, and a male student teacher. The mood of the planning meeting was relaxed but professional, and interactions between triad members were consistently friendly and professional. Engineering Fellow A appeared to be the dominant personality in this triad, though Cooperating Teacher A did not hesitate to push back against her when she felt the developmental needs of her students were being overlooked. Student Teacher A did not make substantial contribution during the planning meeting and appeared happy to work with whatever was agreed upon by his teammates. This triad was observed implementing a segment of an engineering design activity in support of unit on structures of life. Cooperating Teacher A’s approach to classroom was firm but fair; students in this class appeared well-behaved and motivated to work. Students appeared have formed a close bond with Student Teacher A, but were not observed to turn to Engineering Fellow A as frequently with questions or requests for assistance.

Triad B

Triad B was composed of a female cooperating teacher, a male engineering fellow for whom English was not his native language, and a female student teacher. The observed planning meeting took place on a Friday afternoon after the school day had ended. The mood of the meeting was relaxed and friendly, and triad members frequently shared funny stories of student antics among themselves. Cooperating Teacher B and Engineering Fellow B were the dominant voices during the planning meeting; the pair engaged in lengthy discussions in which they
worked to clarify content related to plant anatomy and growth; these discussions centered on content as it would be presented to students and also for Engineering Fellow B, who appeared to have difficulty with some of the concepts. Cooperating Teacher B and Engineering Fellow B appeared to have a close bond, as evidenced by their close collaboration during content discussions and also by shared stories of their respective families. Although she would be teaching the lesson her teammates were planning, Student Teacher B spent much of the planning meeting engaged in tasks unrelated to the meeting; these included searching for materials not relevant to the planning meeting or lesson, talking with other teachers, and playing with a bracelet a student had made for her. Student Teacher B was observed to frequently interrupt her teammates’ work with off-topic anecdotes or off-topic questions; following such disruptions, her teammates would take several minutes to get back on task and thus a considerable amount of time was spent unproductively. During her interview, Student Teacher B expressed feeling that her triad was easily distracted, but during the observed planning meeting she herself was often the source of distractions. This triad presented a lesson focused on terminology related to plant anatomy; approximately 15 minutes of the lesson were given to an ELL cooperating/student teacher pair, who worked with students to reinforce vocabulary items taught in a previous lesson. This class appeared well-managed and was receptive to all triad members.

**Triad C**

Triad C was composed of a female student teacher, a female engineering fellow, and a female student teacher. The observed planning meeting took place during Cooperating Teacher C’s scheduled planning period. The mood during the planning meeting was relaxed yet professional; interactions between triad members were collegial. Student Teacher C appeared to be the dominant personality in this triad. Her ideas for the upcoming observed lesson and for
long range planning of science units were the central focus of the meeting and she spoke at
length about her thoughts. Cooperating Teacher C would at times question her ideas but did not
significantly alter the plans being made by Student Teacher C, indicating that she was likely
receptive to the ideas of Student Teacher C and trusted her professional judgment. Engineering
Fellow C was silent throughout most of the planning meeting; while she did share one content
idea related to measurement of atmospheric properties for purposes of meteorology, her
contribution to the planning meeting was minimal. Several times she was asked questions by
Student Teacher C, who appeared sensitive to Engineering Fellow C’s quietude and may have
been working to help her feel involved in triad planning and decision-making. Cooperating
Teacher C and Engineering Fellow C worked together closely to hone the logical sequencing of
their upcoming lesson on the properties of air; all triad members worked together to ensure they
knew how to use the equipment required for the lesson. The observed lesson the triad presented
was well-sequenced and both pedagogically and conceptually sound. During the lesson, the triad
asked students to compare the mass of rubber playground ball before and after inflation; they
then engaged in a planned and well-managed discussion designed to scaffold student thinking to
the notion that air has mass. However, the science period ended before the triad could reach the
lesson’s denouement. Rather than building to the conclusion that air has mass logically,
Cooperating Teacher C directly told the students what they should know and record in their
notebooks.

**Triad D**

Triad D was composed of a female cooperating teacher, a female engineering fellow for whom
English was not her native language, and a female student teacher. This triad met to plan during
Cooperating Teacher D’s scheduled planning period, following which they would teach the
observed lesson. The atmosphere of the planning meeting was relaxed; interactions between triad members were collegial. Engineering Fellow D and Student Teacher D appeared to have bonded more closely with each other than either had with Cooperating Teacher D. The pair shared stories and friendly conversation throughout the planning meeting; while they both interacted with Cooperating Teacher D in a friendly way, during the planning meeting they appeared to regard her as more of a figure of authority than a peer. Digital technology played an interesting role within this triad. Cooperating Teacher D held her smartphone in her hand throughout the lesson and while engaged with students in a whole-class discussion was observed multiple times to pause instruction to interact with her phone. Also during the observed lesson, Student Teacher D sat at a table in the back of the room and was seen to be clearly involved in a Facebook message exchange, both on her laptop computer and smartphone. During the lesson, she neither addressed nor was addressed by her teammates, nor did she engage with students. Midway through the lesson, while Engineering Fellow D was leading a class discussion, Student Teacher D began to distribute lesson materials to students with no obvious prompting from either of her teammates. Students became distracted once in possession of the materials, and Engineering Fellow D struggled to regain their attention.

**Triad E**

Triad E was composed of a female cooperating teacher, a male engineering fellow for whom English was not his native language, and a female student teacher. This team met for the observed planning lesson during Cooperating Teacher E’s scheduled planning period, after which they would teach the observed co-taught lesson. The atmosphere of the planning meeting was cordial, but evidence of an unbalanced relationship among triad members was apparent. Cooperating Teacher E and Student Teacher E appeared to have a close and friendly relationship,
and Student Teacher E appeared to consider Cooperating Teacher E more a peer than a mentor or supervisor. The triad was in the midst of a unit on the cycles and structures of life, and their observed lesson was to introduce students to the crayfish for whom they would designing a habitat. During the planning meeting, engineering Fellow E appeared motivated to help his teammates plan for the upcoming lesson; early in the planning meeting he shared several lesson ideas and a video link related to crayfish. However, his ideas were summarily rejected by Student Teacher E as being irrelevant to lesson goals; after several attempts to get his ideas heard, Engineering Fellow E fell silent and while remaining attentive to the conversation of his teammates, he made no further contributions to the lesson. No interaction between Engineering Fellow E and Cooperating Teacher E was observed. The observed lesson was well-planned and well-run. Students had formed a clear bond with Engineering Fellow E, and appeared to regard him as being of equal status to Cooperating Teacher E and Student Teacher E. Interestingly, this team appeared to operate as a dyad, with Cooperating Teacher E and Student Teacher E forming one half and Engineering Fellow E representing the other. This was evidenced both by interactions between triad members and by parity signals sent by Cooperating Teacher E. In the first instance, Cooperating Teacher E had asked the class to turn in papers, stating that students could turn in papers either to herself or to Student Teacher E; despite the clear acceptance of Engineering Fellow E by the students, Cooperating Teacher E did not include him as a person who could receive papers. Second, as students were leaving the room for a “specials” class, Cooperating Teacher E and Student Teacher E stood at the door and smilingly saw students out; as they did so, Engineering Fellow E remained in the room and cleaned water from students’ desks. Although in both cases these actions could have simply occurred as happenstance, considered alongside the “shutting down” of Engineering Fellow E by Student Teacher E it
appears possible that Engineering Fellow E was not regarded as a fully equal member of the triad.

**Triad F**

Triad F was composed of a female cooperating teacher, a male engineering fellow for whom English was not his native language, and a female student teacher. Triad F’s observed planning meeting was scheduled to occur before the start of the school day. When the researcher arrived at the school, he was informed that Engineering Fellow F had overslept and was running late; by the time Engineering Fellow F arrived at the school, there was not enough time for planning to occur. The researcher arranged to return in two hours, at which point all triad members would be present. During the second planning meeting, Cooperating Teacher F spent much of the available planning time engaged in long-range planning with a special education teacher, while Student Teacher F graded student papers and Engineering Fellow F sat silently. With approximately 20 min of the second scheduled planning meeting remaining, Cooperating Teacher F asked Engineering Fellow F for help with “engineering themed” mathematics problems; a problem the pair discussed was “An engineer has 49 drawings. If they are arranged in rows of 7, how many total rows will there be?” Cooperating Teacher E asked Engineering Fellow E for help with these problems because she wanted them to be “scientifically correct”. However, only one problem contained actual science or engineering content. This problem was created by Engineering Fellow F and stated “A satellite makes 9 rotations around the Earth each year. How many rotations will it make it 8 years?” This problem contained two content-related issues:

1. The term “rotations” was incorrectly used in place of “orbit”;
2. a satellite exhibiting the stated properties would not have a velocity sufficiently high enough to sustain an orbit. Student
Teacher F did not speak to either Cooperating Teacher F or Engineering Fellow F during this time, remaining instead focused on grading papers. This triad presented a segment of an engineering design activity in support of an energy-themed unit; during the lesson, students designed and built a container that would hold objects to be lifted by windmill. Student Teacher F served as lead teacher for this lesson, with her teammates playing supporting roles.

**Triad G**

Triad G was composed of a female cooperating teacher, a male engineering fellow, and a female student teacher. A researcher tried twice to schedule a planning meeting observation with this triad, but in both instances the visit was called off due to school assemblies. During a subsequent email exchange with Engineering Fellow G, the researcher was invited to observe a planning session that would follow the co-taught lesson. Although this was contrary to the research design of the study, given the prior scheduling difficulties the researcher agreed to attend the meeting. However, upon completion of the lesson, Cooperating Teacher G stated that that team planning would not be held; instead, she had arranged to engage in long-range planning with other teachers. Although not observed during a planning meeting, during the co-taught lesson there were no indications of problematic member relationships within the triad. This triad presented a segment of an engineering design lesson in support of a large-scale unit focused on environments. During this lesson, no indications of problematic member relationships were evident. Students appeared to regard all triad members as figures of authority.
APPENDIX 2. INSTITUTIONAL REVIEW BOARD APPROVAL MEMO

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Date: 6/27/2014
To: Dr. Joanne Olson
N131 Lagomarcino

From: Office for Responsible Research
Title: TEC-STEM Partnerships: Teachers and Engineers Collaborate for STEM in K-5
IRB ID: 14-336

Study Review Date: 6/26/2014

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (1) Research conducted in established or commonly accepted education settings involving normal education practices, such as:
  - Research on regular and special education instructional strategies; or
  - Research on the effectiveness of, or the comparison among, instructional techniques, curricula, or classroom management methods.

The determination of exemption means that:
- You do not need to submit an application for annual continuing review.
- You must carry out the research as described in the IRB application. Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. Only the IRB or designees may make the determination of exemption, even if you conduct a study in the future that is exactly like this study.

Please be aware that approval from other entities may also be needed. For example, access to data from private records (e.g., student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.