AC 2011-628: CLASSROOM TEACHER - ENRICHMENT TEACHER PAIRS: CO-TEACHING AS A MEANS TO IMPLEMENT ELEMENTARY ENGINEERING EDUCATION

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Classroom Teacher - Enrichment Teacher Pairs: Co-Teaching as a Means to Implement Elementary Engineering Education

Abstract

Co-teaching is when teachers work together to prepare to teach, teach, and reflect on teaching and learning. This paper describes the extent and nature of co-teaching by 28 classroom and 8 enrichment teachers from 7 elementary schools as they taught integrated science-technology-engineering units (STE units) of instruction for the first time. Quantitative and qualitative research methods were utilized to explore teacher perspectives on their co-teaching experiences, and to examine how elementary engineering implementation may be enhanced when classroom teachers co-teach with enrichment teachers. Participation in co-teaching varied across participants, largely due to logistical challenges, yet most teachers perceived of co-teaching as an effective and helpful teaching strategy. Recommendations for future classroom/enrichment co-teaching emphasize co-planning and co-teaching the hands-on- and minds-on-intensive engineering design process lessons within STE units.

Introduction

Co-teaching is when teachers work together to prepare to teach, teach, and reflect on teaching and learning. This paper describes the extent and nature of co-teaching by 28 classroom and 8 enrichment teachers from 7 elementary schools as they taught integrated science-technology-engineering units (STE units) of instruction for the first time. The first section of the paper briefly highlights the need to support elementary teachers charged with the task of teaching engineering to children, and then introduces co-teaching as an educational strategy that may provide such support and other benefits. Next, the paper describes the context in which the teachers co-taught, which is followed by a description of the quantitative and qualitative methods used to study their experiences and perspectives. A discussion of the results and the utility of classroom/enrichment co-teacher pairs for implementing elementary engineering education follows the findings section.

Background

Teaching engineering to children is a new practice for most elementary teachers. Many elementary teachers do not consider themselves to be strong in STEM (science, technology, engineering and mathematics) fields that have historically been a part of the elementary school day (i.e., science and mathematics),[1-3] and most have had no exposure to more recent STEM areas, technology and engineering. [4] Cunningham, the national director of the EiE project, offered: "If most elementary teachers are afraid of teaching science, then the notion of teaching engineering is often accompanied by terror". [5] Quality professional development experiences have been shown to bolster practicing elementary teachers' knowledge, confidence and attitudes towards engineering and other STEM subjects. [5, 6, 7] This paper explores another potential means of supporting classroom teachers as they learn to teach engineering: co-teaching.

Co-teaching is a nearly 50-year-old means to facilitate student learning in the classroom. Broadly defined, co-teaching is:

> … two or more people sharing responsibility for teaching some or all of the students assigned to a classroom. It involves the distribution of responsibility among people for planning, instruction, and evaluation for a classroom of students. [8]

Historically, co-teaching has been enacted to differentiate instruction for students who have special needs and learn in inclusive environments. [8-10] Indeed, the vast majority of the literature on co-teaching addresses dyadic co-teaching partnerships between classroom teachers and special educators. [11-13]

One key idea with respect to co-teaching is that each co-teacher has a unique, professional skill set to offer the classroom environment. Having two classroom teachers teaching together (i.e., team teaching), while potentially helpful, does not have the same spirit of co-teaching where a combination of different skill sets provides a unique benefit to the learning environment. [10] For example, in one case study of elementary science co-teaching, the classroom teacher was regarded as the "science content expert" and the special educator was regarded as the "adaptation expert". [14]

Although each co-teacher's skill set has unique elements, co-teachers are peers with regard to level of certification, helping to ensure that "they truly are colleagues who jointly make instructional decisions and share responsibility and accountability." [10] Co-teaching generally does not include a classroom teacher working with a noncertified assistant (e.g., paraprofessional). [9]

Given this focus on blending professional-level expertise to benefit student learning, advocates of co-teaching expect co-teaching to occur in settings in which the expertise of the non-classroom teacher is warranted (i.e., not in a homogeneous setting). Further, for this togetherness to be regarded as co-teaching, co-teachers not only work together in the same classroom at the same time but take up "essential teaching roles." [10] Such roles are to be differentiated from those that are passive (e.g., having one teacher continually in an observational role, or constantly deferent to the other teacher), non-instructional (e.g., photocopying), or peripheral (e.g., being cast only as the behavior monitor or extra pair of hands).

Co-teaching may look quite different to the classroom observer depending upon the approach that co-teachers employ. Villa and colleagues described four basic approaches to co-teaching: supportive, parallel, complementary, and team. [8] These four approaches, summarized in Table 1, were identified as the four predominant co-teaching approaches for inclusive classrooms in a national survey of teachers. [15] No one co-teaching approach is necessarily better than the other, and each has drawbacks.

The quality of the co-teaching experience for teachers and students is impacted by a number of mediating variables, addressed extensively in the literature. Seminal work by Adams & Cessna, [16] validated repeatedly in the literature, used extensive interview data with co-teaching pairs to identify essential components for successful co-teaching. [10] One of those is the need for co-teachers to have their own expertise, professional knowledge and credentials (mentioned

previously). Ideally, co-teachers should have a similar set of beliefs about teaching and learning (e.g., about teacher responsibilities), and should discuss and negotiate any differences in these beliefs. Also helpful is a supportive atmosphere for co-teaching via administrative support and opportunities for co-teaching professional development.

Table 1: Summary of four approaches to co-teaching (Villa and colleagues). [8] Note: Do not assume that co-teacher A is the classroom teacher; this may be the case, but is not necessarily so.

Approach	Co-Teacher A	Co-Teacher B
Supportive	Takes the lead teaching role.	Monitors students, provides support and assistance to students.
Parallel	Work with one group of students in one part of the classroom; may rotate to other group.	Work with another group of students in one part of the classroom; may rotate to other group.
Complementary	Takes the lead teaching role.	Enhances instruction provided by other co-teacher (e.g., interjects ideas or questions, paraphrases, may pre-teach a small group prior to lesson).
Team	Simultaneous delivery of the lesson. Leader and supporter roles alternate between co-teachers throughout the lesson.	

In addition to the prerequisite knowledge, beliefs, and context for co-teaching, co-teachers' behaviors can impact the quality of co-teaching.[10, 16] Co-teachers should be personable, supportive, and collaborative (i.e., value one another's contributions, share goals and responsibilities). Also, co-planning for instruction is an essential part of maximizing co-teaching value, especially for team co-teaching approaches. [8] The importance of co-planning is evidenced by the wide array of co-planning instruments published to guide the co-planning process. [12, 17]

The primary intent of co-teaching is to enhance student learning. However, evidence of a positive relationship between co-teaching and positive student learning outcomes is relatively small. [18, 19] Weiss argued that co-teaching was an example of how "advocacy for a practice can outpace the science that supports it." [18] One challenge for co-teaching—indeed an area of study in itself [13, 14]—is that co-teaching is implemented in a wide range of ways, some less than ideal. This makes studies of the impact of co-teaching on student outcomes difficult to employ. [19] A recent study was able to control for fidelity of co-teaching implementation and found that students with disabilities experienced greater gains in academic and behavioral performance during a year when they were co-taught than in the prior year when no co-teaching occurred. [11]

Another potential impact of co-teaching is on the teachers themselves:

> … co-teaching provides professionals with a sense of support, that is, the knowledge that ensuring students reach their educational goals is not a responsibility that has to be undertaken in isolation. [10]

One study suggested that co-teaching is not only supportive, but may be potentially transformative for teachers. [20] In this study, preservice teachers specializing in science education were paired with classroom teachers. Although typically, preservice teachers are expected to receive the primary benefit from this relationship, in this case, the benefit was reversed. Classroom teachers had no supervisory responsibilities or mentoring roles, and instead, were asked to plan and teach collaboratively with the preservice teachers. The preservice teachers' involvement significantly increased the extent to which hands-on, inquiry-based instruction in science occurred in the classroom, increasing measures of children's learning of and enjoyment of science as compared to a non-co-taught control group. These positive student outcomes may be attributed in part, suggested the authors, "to enhanced [classroom] teacher confidence in investigative science and technology teaching as a result of their work with the science specialist students." [20]

Context & Participants

The 36 teachers involved in the present study—including 15 3rd grade, 13 4th grade, and 8 enrichment teachers—were participants in the 2009-2010 pilot year of the SySTEmic Project. This project aims to provide one science-technology-engineering integrated unit of instruction (hereafter, "STE unit") to all 15,000 1st through 5th grade children in a 40,000-pupil district by 2013. The STE units are blends of modified district science units and Engineering is Elementary (EiE) units (Table 2), and were designed to utilize 12 to 14 hours of instructional time.

Table 2: Pilot Year (3rd & 4th grade) STE Units for SySTEmic Project.

	3rd Grade	**4th Grade**
Original District Science Unit	Energy in Motion	Rocks & Minerals
EiE Unit	Catching the Wind: Designing Windmills	A Sticky Situation: Designing Walls
STE Unit	Motion, Energy & Mechanical Engineering	Rocks, Minerals & Materials Engineering

Each STE Unit has one long (90 – 120 minute) engineering design process lesson that represents the culmination of the unit. The engineering design process involves five steps, as described by the EiE curriculum, in which students identify a problem, brainstorm ways to solve the problem, select one way to solve the problem and plan for their first design, build and test their first design, and create and test a second design that aims to improve upon the first. [21] In the 3rd grade unit, the engineering design process lesson involves designing windmill blades for a model windmill that lifts a cup when it spins. In the 4th grade unit, students design the mortar and rock pattern to create a strong wall. These lessons require different materials for the building process and apparatuses for the testing process; further, the lessons involve students continually reflecting on prior knowledge developed prior to (e.g., about material properties) or during (e.g., testing results) the engineering design process to make reasoned decisions about their first and second designs.

Pilot year teachers who taught these units were from 7 of the 33 elementary schools across the district (Table 3). These pilot schools are where each STE unit within the SySTEmic Project is taught one year prior to full implementation in the district. The pilot schools represent a diversity of size, socio-economic status and ethnicity of the student body, and geographic location within the district. All enrichment teachers at these schools agreed to participate early in the development of the SySTEmic Project. Those enrichment teachers helped to recruit 3rd and 4th grade teachers for the pilot year. Classroom teachers who ultimately participated in the project voluntarily chose to participate. In some pilot schools, all grade level teachers participated in the pilot year; in others, only a subset of 3rd or 4th grade teachers participated.

Prior to teaching the STE units, all teachers received 9 hours of professional development (PD) to learn both unit content and pedagogy. Enrichment teachers participated in PD for both 3rd and 4th grade units. Classroom teachers attended a single session for their grade level only.

Table 3: SySTEmic Project pilot schools, school characteristics, and participants.

School	School Characteristics				Study/Pilot Year Participants		
	Size of school	School setting	Title I?	Approx % Minority students*	# Enrichment teachers	# 3rd Grade Teachers in Pilot	# 4th Grade Teachers in Pilot
A	Medium	Rural	No	10%	1**	1	1
B	Medium	Rural	No	5%	1	3	2
C	Small	Rural	No	15%	1**	1	1
D	Medium	Small city	Yes	60%	1	2	3
E	Large	Suburban	No	15%	2**	3	3
F	Medium	Small city	Yes	50%	1	3	1
G	Large	Suburban	No	15%	1	2	2
				Totals ⇨	8	15	13

** Rounded to nearest 5%; Minority includes: American Indian/AK Native, African American, Asian/Pacific Islander, & Hispanic.*
*** Positions are part-time (1/2 time each in schools A and E; 1/5 time in school C).*

Although 36 classroom teachers were involved in the SySTEmic Project, 49 classrooms of children were taught an STE unit during the pilot year. Ten classroom teachers taught the STE unit to more than one classroom of students: 8 taught the unit to 2 classrooms (their own and another teacher's students); one taught the unit to 3 classrooms; and one taught the unit to 4 classrooms. Teaching occurred: in a serial fashion for 6 of the 10 teachers (i.e., one classroom completed the unit before another began); in a parallel fashion for 3 teachers (i.e., two classrooms learned the unit during the same period of time, e.g., at two different times on the same day), and in a serial/parallel combination for one teacher (i.e., once two classrooms taught in a parallel fashion completed the unit, another two classrooms were taught in parallel).

During PD, SySTEmic Project leaders explained to pilot year teachers why enrichment teachers would be involved in the project. Enrichment teachers were included: as a means of support to classroom teachers; as a resource to the project based upon many of their prior experiences with engineering design challenges in after school activities like Destination Imagination, FIRST Lego League and the state's Engineering Challenge competition; and to help develop extensions for the integrated units. A presentation slide used in PD by a project/district leader described the different kinds of expertise that classroom and enrichment teachers could bring to the project, with the caveat that both kinds of teachers are likely to have expertise beyond their respective lists (Table 4).

Table 4: Classroom and enrichment teacher expertise, taken verbatim from a presentation slide presented to all pilot year teachers during PD

Classroom Teacher's Expertise	Enrichment Teacher's Expertise
• Science Curriculum • Work with ALL Students • Differentiation • Teaching Across the Curriculum (Integration)	• Science & Engineering Concepts • EiE Resource in School to ALL Teachers (Advocate of the program) • Possible Classroom Support – Co-Planning & Co-Teaching Model • Higher Level Questioning/Critical Thinking • Provide Extensions/Enrichment as Needed for Identified Students

Note that some of the kinds of expertise listed under "enrichment teacher" in Table 3 may be relevant to individuals in some districts called "science specialists" or "STEM specialists" or other similar titles. Such individuals are science/STEM focused, available to assist teachers with these content areas, yet not tied to a particular classroom. No such positions exist within the district in which the SySTEmic Project takes place.

Included under enrichment teacher expertise in Table 4 is "Possible Classroom Support – Co-Planning and Co-Teaching Model". The use of the word "possible" here alludes to the idea that co-planning and co-teaching could not be mandated in the SySTEmic Project. Rather, co-planning and co-teaching were strongly encouraged by project leaders. It is important to consider some constraints of enrichment teachers when considering their SySTEmic Project co-teaching involvement:

- Enrichment teachers have many responsibilities beyond the SySTEmic Project.
- Enrichment teachers may or may not be full time (see Table 3).
- Some enrichment teachers work in very large schools (e.g., School G; see Table 3).
- Each enrichment teacher is working with 2 to 5 classroom teachers (see Table 3) for the SySTEmic Project.

Broadly, the enrichment teachers' focus is to extend and enhance learning for students in pre-K-5. To do so, enrichment teachers engage in some balance of: consulting/co-planning with teachers to help those teachers build all students' creative and critical thinking skills and to challenge high

achieving students during instruction; co-teaching within teachers' classrooms to help teach enrichment lessons to large groups of students or more targeted lesson enhancement to small, clustered groups of students; and providing pull-out experiences for small groups of students who have already mastered content that the classroom teacher is teaching. Although it is not uncommon for enrichment teachers to engage in these practices for science or social studies, their main focus is on the more heavily tested subjects: integrated language arts and mathematics. Enrichment teachers' specific responsibilities vary throughout the district, and depend on multiple variables including Title I status and the principal's school plan.

Research Questions

This study aimed to investigate pilot year classroom and enrichment teachers' perspectives on the nature and value of their co-teaching experiences, and how co-teaching may enhance elementary engineering implementation. Research questions were as follows:

1. To what extent did SySTEmic Project teachers co-teach and co-plan? What factors seemed to influence the extent of co-teaching and co-planning?

2. What past co-teaching experiences and perspectives about STE-unit co-teaching did SySTEmic Project teachers have prior to teaching the STE units? How did perspectives about co-teaching the STE units change after teaching the units?

3. What co-teaching approaches (i.e., supportive, parallel, complementary, team) did SySTEmic Project teachers employ? What factors seemed to influence the approaches that teachers used?

4. What unique contributions did enrichment teachers make—or could they make—to STE unit instruction as co-teachers?

In addition, ten null hypotheses were tested using quantitative methodologies described in the following section. These null hypotheses are as follows:

H_{01}: There is no difference between the frequency with which classroom teachers anticipated co-teaching (prior to teaching the STE unit) and the frequency with which co-teaching actually occurred. (H_{01}: anticipated co-teaching frequency = actual co-teaching frequency).

H_{02}: There is no difference between classroom teachers' and enrichment teachers' perceptions about their comfort with co-teaching and the benefits of co-teaching prior to teaching the STE unit. (H_{02}: classroom teacher perceptions about co-teaching prior to teaching = enrichment teacher perceptions about co-teaching prior to teaching.)

H_{03}: There is no difference between classroom teachers' and enrichment teachers' perceptions about their comfort with co-teaching and the benefits of co-teaching after teaching the STE unit. (H_{03}: classroom teacher perceptions about co-teaching after teaching = enrichment teacher perceptions about co-teaching after teaching.)

H_{04}: There is no difference between teachers' perceptions (about their comfort with co-

teaching and the perceived benefits of co-teaching) before teaching the STE unit as compared to their perceptions after teaching the STE unit. (H_{04}: teacher perceptions about co-teaching prior to teaching = enrichment teacher perceptions about co-teaching after teaching.)

H_{05}: There is no difference among the frequencies with which teachers anticipated using the four approaches to co-teaching (supportive, parallel, complementary, and team). (H_{05}: teachers' anticipated frequency using supportive approach = teachers' anticipated frequency of using parallel approach = teachers' anticipated frequency of using complementary approach = teachers' anticipated frequency of using team approach).

H_{06}: There is no difference between the range of frequencies of co-teaching approaches (supportive, parallel, complementary, and team) as anticipated by classroom teachers and enrichment teachers. (H_{06}: enrichment teacher frequencies of anticipated co-teaching approaches = classroom teacher frequencies of anticipated co-teaching approaches).

H_{07}: There is no difference among the actual frequencies with which teachers used the four approaches to co-teaching (supportive, parallel, complementary, and team) during the STE unit. (H_{07}: teachers' actual frequency using supportive approach = teachers' anticipated frequency of using parallel approach = teachers' anticipated frequency of using complementary approach = teachers' anticipated frequency of using team approach).

H_{08}: Roles that enrichment teachers assume in the SySTEmic Project are perceived by teachers as being equally important to new (i.e., new to teaching an STE unit) and veteran (i.e., with prior STE unit teaching experience) classroom teachers. (H_{08}: for any role, the importance of that role to benefit new classroom teachers = the importance of that role to benefit veteran classroom teachers; roles are identified and clarified in a forthcoming section "Enrichment Teacher Contributions").

H_{09}: For each role that enrichment teachers assume in the SySTEmic Project, there is no difference between the importance of that role as perceived by enrichment teachers and the importance of that role as perceived by classroom teachers (H_{09}: for any role, the importance of that role as perceived by enrichment teachers = the importance of that role as perceived by classroom teachers; roles are identified and clarified in a forthcoming section "Enrichment Teacher Contributions").

H_{10}: There is no difference in the degree of importance placed on the different roles that enrichment teachers take on as co-teachers of the STE units. (H_{10}: role "a" importance = role "b" importance = role "c" importance … where a, b, and c are identified and clarified in a forthcoming section "Enrichment Teacher Contributions").

Methodology

Both quantitative and qualitative methods were employed to answer the above research questions. Surveys generated quantitative data, and interviews provided further qualitative depth to teachers' perspectives on co-teaching. Survey development, data collection, and analysis will

be discussed first, followed by a discussion of interview methodology.

The author and a colleague designed a pre- and post-teaching survey to examine pilot year teachers' perspectives on planning to teach and teaching the STE units. Survey items were developed after analysis of extensive interviews with and observations of two classroom-enrichment co-teaching pairs who taught an STE unit as a pre-pilot in the spring of 2009. This analysis, coupled with discussions with other SySTEmic Project and district leaders, resulted in the range of questions about co-teaching included in the surveys.

Approximately one third of the pre- and post-teaching surveys were dedicated to questions about co-teaching. Most questions regarding co-teaching asked participants to answer on a Likert scale with regard to level of agreement or degree of importance. For example, teachers were asked to express their level of agreement regarding their comfort with co-teaching the STE unit. Some questions asked for numerical responses [e.g., on the post-teaching survey: During approximately how many lessons did you and the enrichment teacher co-teach in your classroom (i.e., actual time spent together with students)?] Other questions were multiple choice (e.g., During what kinds of lessons did you co-teach? a. science lessons, b. engineering lessons, or c. both science and engineering lessons.)

Surveys were sent electronically to classroom teachers via the online survey software, SurveyMonkey™. Classroom teachers who taught the unit to multiple classes of students were asked to complete the post-teaching survey after teaching all of their classes. Enrichment teachers were sent pre-surveys prior to working with classroom teachers, and were asked to complete post-teaching surveys after completing all work with classroom teachers in their buildings. SySTEmic Project leaders tracked when each teacher would teach the STE unit(s) and teachers received as many as three reminders to complete surveys. Response rates for the surveys were quite high: 100% pre-teaching survey; and 94.4% post-teaching survey, including one individual who completed some, but not all questions on the survey. Teachers who were involved in the pilot year signed a "pledge" acknowledging that their grant-funded stipend to participate in the project included not only payment for additional time required for implementation, but also for participation in surveys. (Those who did not complete post-teaching surveys received no negative repercussions as a result.)

Analysis of survey results involved a combination of descriptive and inferential statistics. In this paper, medians and frequencies of responses to Likert-scale questions were used in favor of means and standard deviations given the nonparametric nature of the data. Two types of non-parametric tests were used in the quantitative analysis program, SPSS®, to accept or reject the null hypotheses. [22] Responses—especially those for the relatively small sample of enrichment teachers—tended to have non-normal distributions, thus suggesting that non-parametric tests such as the Mann-Whitney-Wilcoxon (MWW) were more powerful than t tests. [23] MWW was used to determine differences between enrichment and classroom teachers. [24] The Wilcoxon Matched-Pairs Signed-Rank test was used to examine differences in teacher response to the same questions across time (e.g., comparing post- and pre-teaching), or to the differences in the degree of importance teachers placed on enrichment teacher roles. Two-tailed significance was reported since the directionality of deviation from the null hypotheses was not predictably in one direction

prior to data collection or analysis for any of the variables studied. The significance level reported throughout this study was 0.05.

After post-teaching surveys had been collected, classroom and enrichment teachers were invited to participate in an interview to elaborate their post-teaching survey results and overall perspectives on factors that enhanced or were barriers to teaching the STE unit(s). [25] The co-teaching portion of the interview protocol asked teachers to reflect on their overall co-teaching experiences, discuss the different approaches to co-teaching that they used (supportive, parallel, complementary, and team), discuss the most important roles for enrichment teachers to have in the SySTEmic Project, and to describe what the "ideal" co-teaching experience would look like for the STE unit. Prior to each interview, the author reviewed the post-teaching survey responses for that particular teacher and recorded individual follow-up questions on the interview protocol form to individualize the interview process.

Of the 36 pilot year teachers, 21 (nearly 60%) participated in interviews; of these, 8 were 3rd grade teachers, 8 were 4th grade teachers, and 5 were enrichment teachers. Teachers were paid a modest, grant-funded stipend for their time. Interviews were semi-structured in format, [26] lasted approximately 1 hour, and were digitally recorded. They took place at the teacher's school or home. Discussions about co-teaching were approximately one quarter of the interview duration. Interviews were transcribed, and all interviewees—as well as any other participants in the study who were named in interviews—were psuedonymed.

The first level of qualitative analysis involved a grounded theory approach, which involved iterative reviews of the transcripts to search for recurrent themes. [27, 28] Throughout this process, codes were identified, refined, and at times removed or renamed; ultimately, a list of 22 co-teaching codes was finalized, after which the transcripts were coded with the final code set using the qualitative analysis software, HyperResearch™.

Participant Observation Role

The author's role in this study and in the SySTEmic Project is one of participant-observation, a role common to qualitative research. [26] As a participant, the author is instrumental in blending the science and EiE units to create the STE units, and is the lead professional developer for all pilot year teachers (this is ongoing work). These experiences afford the author many benefits of insight and understanding, including the ability to write contextually informed survey and interview questions. However, teachers may be less inclined to be critical of the project since they are reporting survey responses to the author and, for those who took part in the interview process, sharing their ideas verbally with the author.

Findings

This section has been organized into six sub-sections that speak to the research questions. The subsections are: Past Co-Teaching Experiences, Extent of Co-Teaching, Extent of Co-Planning, Co-Teaching Perspectives, Co-Teaching Approaches, and Enrichment Teacher Contributions. Quantitative and qualitative data findings intermingle in the subsections as appropriate.

Past Co-Teaching Experiences

On the pre-teaching survey, classroom teachers were asked to approximate the extent to which they had co-taught with the enrichment teacher outside of the SySTEmic Project. Approximately 39% (n = 11 out of 28) had not co-taught with the enrichment teacher at all in the past. Another 39% of classroom teachers had co-taught with the enrichment teacher once per week or more during the pilot or a prior school year. The remaining 22% (n = 6) had worked with the enrichment teacher in the past, yet less frequently [i.e., once per month (n = 1), once per year (n = 3), on an as-needed basis (n = 1), or only during the SySTEmic Project pre-pilot in the prior year (n = 1)].

Some participants described past co-teaching experiences during interviews. Theresa, an enrichment teacher, co-taught eleven times per week in her school, working with all but one classroom teacher in the building. She reflected positively on her working relationship with Jacqueline, with whom she co-taught reading: "… we just have that genuine like and respect for each other." Susan, Julie, and Heather, classroom teachers, described their working relationships with their respective enrichment teachers in similarly positive ways (e.g., "we think alike," "we're just comfortable with each other," "we just get along very well").

Many classroom teachers had co-taught previously with special educators. Katie shared that prior to this project, "I've never co-taught with another teacher to a general ed classroom. I've always co-taught … with a mix of special ed [sic] and general ed [sic]." Julie had "a lot of co-teaching experience" with special educators, and said, "I don't mind sharing a space … [or] planning with people. I enjoy it." Denise, however, had never co-taught with a special educator in her nearly ten years as a classroom teacher.

Extent of Co-Teaching

Of the 28 classroom teachers in the SySTEmic Project, 21 (75%) reported on the post-teaching survey that they had co-taught one or more STE unit lessons with the enrichment teacher. Of these classroom teachers, 67% (n = 14) co-taught both engineering and science lessons in the STE units, and 23% (n = 7) co-taught only the engineering lessons within the units (none co-taught science lessons only).

Seven classroom teachers (six 3rd grade and one 4th grade) did not co-teach largely because of real or perceived conflicts with enrichment teacher schedules. Of these: two interacted with the enrichment teacher to co-plan for the unit; two were in a pre-pilot school, and were aided by an experienced STE unit teacher and instructional materials previously developed by the enrichment teacher; and three had no communication with the enrichment teacher at all. Two of the seven teachers participated in interviews. Ellen, who was able to co-plan but not co-teach with the enrichment teacher shared that "it would have been nice to have someone in the room," yet her enrichment teacher had numerous scheduling conflicts. Sharon explained that she and two other classroom teachers at her grade level were locked into a block of time to teach the unit that the enrichment teacher's schedule "didn't really fit into." Even if the enrichment teachers' schedule was modified, Sharon explained, "she [the enrichment teacher] would split

that time and … we didn't want to be held up in our units so we went forward [without co-teaching]." A discussion with the enrichment teacher regarding the potential for schedule modification never took place.

Classroom teachers anticipated co-teaching more lessons (as reported in the pre-teaching survey), than they actually co-taught (as reported in the post-teaching survey) ($p < 0.01$; H_{01} rejected). The 3rd grade teachers anticipated co-teaching, on average, 4 (median) of the 9 total lessons in the 3rd grade STE unit (min = 1; max = 8), and these teachers actually co-taught, on average, 1.5 lessons (min = 0; max = 8). (Note that one 3rd-grade teacher's pre-/post-teaching data were removed because the teacher anticipated co-teaching more lessons than existed for the STE unit.) On average, 4th grade teachers anticipated co-teaching 5 of the 12 total lessons in the 4th grade STE unit (min = 4; max =11), and these teachers actually co-taught 4 lessons (min = 0; max =10). Classroom teachers who taught the 3rd or 4th grade STE unit to more than one classroom of students (n = 10) were asked to report co-teaching frequency for the classroom in which they co-taught the most. Of these 10 multiple-classroom teachers, 1 did not co-teach, 4 indicated that they co-taught the same amount across classrooms, and 5 reported co-teaching more frequently with one classroom of students than the others. There were two reasons for disparities in co-teaching across classrooms: 1) the enrichment teacher's schedule (100%; n = 5); and 2) the enrichment teacher's assistance was not needed as much as the classroom teacher taught the unit for the second or third time (40%; n = 2). Becky, who taught an STE unit to 3 classrooms of children explained that co-teaching with the enrichment teacher "… just helped me out. I didn't have to do it all by myself and that made it even easier for me to teach the second and third because I was already set up."

Post-teaching survey data from enrichment teachers provide additional information regarding the frequency with which co-teaching occurred in the SySTEmic Project. Overall, each enrichment teacher co-taught with between 1 and 5 classroom teachers to between 1 and 11 total classrooms of children (Table 5). Only 5 enrichment teachers (62.5%) co-taught the 3rd grade unit during the pilot year; of those, 3 co-taught science and engineering lessons and 2 co-taught only engineering lessons. Two enrichment teachers co-taught the 3rd grade unit in the pre-pilot year; one of those was unable to co-teach during the pilot year due to scheduling difficulties. All 8 enrichment teachers co-taught the 4th grade unit with classroom teachers. Most enrichment teachers (75%, n = 6) co-taught both science and engineering lessons in this unit, one (12.5%) enrichment teacher co-taught engineering lessons only, and another co-taught science lessons only.

On post-teaching surveys, enrichment teachers were asked to report the number of lessons in each STE unit for the respective 3rd and 4th grade classrooms in which they most frequently co-taught. In the 3rd grade most-frequently co-taught classrooms, the enrichment teachers co-taught the 9-lesson STE unit for, on average, 3 (median) lessons (min =0; max = 8). (Considering only the 5 enrichment teachers who co-taught the 3rd grade unit, the median shifts to 7 and min to 3.) The enrichment teachers co-taught, on average, 6 of the 12-lesson 4th grade STE unit lessons (min = 3; max = 10) in the 4th grade most-frequently co-taught classrooms. On pre-teaching surveys, enrichment teachers were asked to anticipate the number of lessons they would co-teach for the 4th grade unit only (3rd grade anticipations were inadvertently left out of the survey). There was no significant difference between the enrichment teachers' anticipated

frequency of co-teaching the 4th grade unit and actual co-teaching frequency in the most-frequently co-taught 4th grade classrooms.

A majority of the enrichment teachers and classroom teachers who participated in interviews explained that enrichment teacher schedules were significant barriers to finding time to co-teach. As described in the context section of this paper, most enrichment teacher responsibilities fall outside of the SySTEmic Project. Beyond these demands on enrichment teachers' time, enrichment teachers often have multiple classroom teachers teaching the STE units at the same time. As Jean explained, her enrichment teacher was "trying to spread herself among three [STE] classrooms" and "she did the best she could do."

A caveat with regard to the survey data that was elucidated in interviews is that reported frequencies of co-teaching depend on teachers' operational definitions of co-teaching. For some, a co-teaching relationship that largely utilizes supportive co-teaching approaches may not be legitimately called "co-teaching." However, as Nancy shared, supportive co-teaching is a legitimate "facilitating the teacher kind of model." Genuine co-teaching for some teachers entailed an equitable distribution of work; as Susan, said, "if co … is implying equal then it's not equal". Further, some teachers argued that it was not co-teaching if no prior planning was involved.

Table 5: Number of classroom teachers (out of n = 15 3rd grade and n = 13 4th grade) with which and classrooms (out of n = 49) in which enrichment teachers reported co-teaching.

Enrichment Teacher ID	3rd Grade STE Unit		4th Grade STE Unit		Both STE Units (totals)	
	# classroom co-teachers	# classrooms in which co-teaching occurred	# classroom co-teachers	# classrooms in which co-teaching occurred	Total # classroom co-teachers	Total # classrooms in which co-teaching occurred
1	0	0	1	1	1	1
2	1	3	1	3	2	6
3	1	1	1	1	2	2
4	3	7	2	4	5	11
5	2	1	3	2	5	3
6	2	5	2	2	4	7
7	0	0	1	1	1	1
8	0	0	1	1	1	1
Totals	9	17	12	15	21	32

Perhaps because of disparities between operational definitions of co-teaching and lived experiences on the SySTEmic Project, a few classroom teachers—all of whom reported having co-taught at least once on the surveys—questioned during the interviews if their relationships with enrichment teachers were appropriately labeled "co-teaching." For example, Denise offered:

> Well, I co-taught with Barbara. I don't know if it was really co-teaching. It was more like she was in a supportive role of me … She set up tracks and things like that … and she would be there to support me, to talk with the kids … It wasn't really co-teaching. It was more like … we were helping each other. We weren't planning it together … we weren't coming up with a daily plan or anything like that. (Denise)

Similarly, Jean shared, "it wasn't what I would call co-planning or co-teaching … I did everything and she just kind of popped in [for] 20 minutes." Katie expressed doubts, as well, and suspected that there was "supposed to be a more of a cohesive co-teaching feel" to her relationship with the enrichment teacher based on the nature of the survey questions, but "there wasn't" such a feel (despite co-teaching 5 of 12 lessons with her enrichment teacher). Her co-teacher, a part-time enrichment teacher whom she respected immensely, had a schedule that made co-teaching interactions less frequent than she would have liked.

Another idea made clear in the interviews was that satisfaction with co-teaching (not directly measured in surveys) varied across participants and was not necessarily dependent upon co-teaching frequency. For example, classroom teachers Becky (who co-taught 4 times) and Karen (4 times) described their co-teaching relationships as being close to ideal, while Angela (4 times), Scott (10 times) and Ann (5 times) expressed that they would have liked for more co-teaching to have occurred.

Extent of Co-Planning

There was a wide range of co-planning among SySTEmic Project teachers as reported by classroom teachers (n = 26) in the post-teaching survey (Table 6). Three (11.5%) classroom teachers did not communicate with their enrichment teacher at all. Four (15.4%) teachers exclusively used in-person means of communication [at low (11.5%, n = 3) and medium (3.8%, n = 1) levels]. Most classroom teachers (73.1%, n = 19) reported using a combination of in-person meetings and email/phone communication to co-plan. Levels of these combinations of interactions varied: low in-person, low email/phone (n = 3); low, medium (15.4%, n = 4); low, high (15.4%, n = 4); medium, medium (11.5%, n = 3); medium, high (19.2%, n = 5).

Table 6: Co-planning in-person meeting time and email/phone interactions for the STE unit as reported on the post-teaching survey (n = 26).

Frequency Level	Co-Planning In-person Meeting Time % Classroom Teachers		Co-Planning Email/Phone Interactions % Classroom Teachers	
None	Did not meet	12%	Had no email/ phone calls	27%
Low	Met for less than 1 hour	35%	Had 1 to 4 emails/phone calls	31%
Medium	Met for 1 to 2 hours	35%	Had 5 to 8 emails/phone calls	27%
High	Met for 3 + hours	19%	Had 9 + emails/phone calls	15%

Prior to teaching, classroom teachers (n = 28) were asked if they would like to have more time to plan with the enrichment teachers; 89% said "yes" and 11% said "no". Responses were

similar for the post-teaching survey (n = 25), where 81% responded "yes" and 19% responded "no" to: Would you have liked to find more time to plan and prepare with your co-teacher?

In another question on the post-teaching survey, teachers were asked to select a description (in a multiple choice format) of the amount of co-planning they experienced and their resultant feelings of comfort and preparedness (Table 7). Note that 77% (n = 20 of 26) felt comfortable and prepared all or most of the time, despite how often they met (choices B, D, G, & H). The remainder (23%; n = 6) sometimes or often desired more planning to feel more comfortable and prepared (choices A, C, E & F in Table 7). This group was not significantly different than those who felt comfortable and prepared with regard to past experiences with the enrichment teacher; i.e., they were not disproportionately more likely to have had no prior experiences with the enrichment teacher. Further, this group was not significantly different than the rest with regard to the amount of planning time or number of emails/phone calls exchanged between them and their respective enrichment teachers.

Table 7: Descriptions of the amount of co-planning with enrichment teachers as reported by classroom teachers (n = 26) (multiple choice; single response question).

Descriptions of the Amount of Co-Planning (Multiple Choice Options)		% Classroom Teachers (n = 26)
A.	Non-existent; Need for more – We never met, and as a result, I often felt uncomfortable and underprepared.	4%
B.	Non-existent; Okay – We never met, but I still felt comfortable and prepared.	12%
C.	Minimal; Need for more – We rarely met, and as a result, I often felt uncomfortable and underprepared.	-
D.	Minimal; Okay – We rarely met, but I still felt comfortable and prepared.	27%
E.	Variable; Need for Improvement – A few times, I felt that we met enough so that I felt comfortable and prepared; often, I wish we would have met more to plan.	12%
F.	Variable - Some of the time I felt that we met enough so that I felt comfortable and prepared; sometimes, I wish we would have met more to plan.	8%
G.	Variable; Largely Good – Most of the time, I felt that we met enough so that I felt comfortable and prepared; occasionally, I wish we would have met more to plan.	27%
H.	Ample – We met enough so that I felt as comfortable and prepared as possible with our plan.	12%

On post-teaching surveys, enrichment and classroom teachers were asked to select from a list any barriers or challenges to communicating with their co-teachers (Table 8). They were also able to submit any additional barriers in an open-ended text box response. Only two classroom teachers and one enrichment teacher indicated that they had no barriers to communication. Three

who had no communication with their enrichment teacher responded with "N/A". Having common time to meet, especially given the enrichment teacher's schedule, and other higher-priority responsibilities (both professional and personal) were significant barriers to co-planning. Other barriers and challenges to co-teacher communication included: the part-time status of some enrichment teachers, lack of interest in co-teaching by some classroom teachers, and when one enrichment teacher is working with multiple classroom teachers who have identical schedules.

Table 8: Challenges to communicating and co-planning with co-teachers (post-teaching survey).

Challenge / Barrier	% Classroom teachers (n = 26)	% Enrichment Teacher (n = 8)
Having free time in our schedules that overlap	54%	63%
Having free time in enrichment teacher's schedule	46%	50%
Other priorities have taken precedence for one/both of us	42%	75%
Having free time in classroom teacher's schedule to meet	35%	63%
Remembering to do this in the midst of other responsibilities	19%	38%
N/A (no communication)	12%	-
We did not encounter significant barriers	8%	13%

Perceptions about Co-teaching

On the pre-teaching survey, teachers were asked to indicate their level of agreement with six statements regarding their comfort with co-teaching, and their beliefs about co-teaching as an effective teaching approach, a means to enhance student learning, and a means to differentiate instruction for a diverse group of learners (Table 9). Teachers responded to the statements using the following Likert scale: 6 = strongly agree, 5 = agree, 4 = slightly agree, 3 = slightly disagree, 2 = disagree, 1 = strongly disagree. In the post-survey the first statement ("I feel comfortable co-teaching in general.") was omitted, the tense of some questions was modified slightly, and another response option, "N/A," was provided for those who did not co-teach.

Prior to teaching the STE unit, most classroom and enrichment teachers were comfortable with co-teaching in general and as a means to teach the unit, and believed that co-teaching would benefit instruction and student learning (Table 9). Enrichment teachers more strongly agreed with the statements "Student learning in this unit will be enhanced by two teachers" ($p < 0.05$) and "I believe this unit is most effectively taught using a co-taught approach" ($p < 0.05$). Enrichment teachers more strongly disagreed with the statement "I would feel more comfortable teaching this unit alone" ($p < 0.05$). Thus, H_{02} was rejected for these measures, yet accepted for other measures reported in Table 9. These differences are not surprising in that enrichment teachers' jobs involve enhancing and extending classroom instruction (not teaching units independently) to add value to students' learning experiences.

There was no significant difference between the extent to which enrichment and classroom teachers agreed with statements about co-teaching comfort and beliefs on the post-

teaching survey (H_{03} accepted). However, a comparison of pre- and post-teaching surveys—which excluded those who had not experienced co-teaching (n = 7)—revealed significant differences for two questions (Table 10). The data suggested that by the post-teaching survey, teachers were still comfortable with co-teaching and believed that the STE units were most effectively taught via co-teaching, yet perceived impacts of co-teaching on student learning and differentiation were somewhat less than anticipated. H_{04} was thus rejected with regard to measures of impacts on student learning and differentiation, yet accepted for other measures reported in Table 10.

Table 9: Classroom and enrichment teachers' beliefs about co-teaching in the pre-teaching survey. 6-point Likert scale: Strongly Agree = 6, Agree = 5, Slightly Agree = 4, Slightly Disagree = 3, Disagree = 2, Strongly Disagree = 1. * = $p < 0.05$; H_{02} rejected.

	MWW Result	Classroom teachers (n = 28)				Enrichment teachers (n = 8)			
		Median (/6)	Frequencies (%)†			Median (/6)	Frequencies (%)†		
			Agree or Strongly Agree	Slightly Agree or Slightly Disagree	Disagree or Strongly Disagree		Agree or Strongly Agree	Slightly Agree or Slightly Disagree	Disagree or Strongly Disagree
I feel comfortable co-teaching in general.	0.302	5	90%	10%	-	6	88%	12%	-
I feel comfortable co-teaching this unit.	0.302	5	86%	14%	-	6	88%	12%	-
I would feel more comfortable teaching this unit alone.	**0.049 ***	2	18%	18%	64%	1.5	-	12%	88%
I believe that this unit is most effectively taught using a co-taught approach.††	**0.034 ***	5	74%	22%	4%	6	100 %	-	-
Student learning in this unit will be enhanced by having two teachers.	**0.030 ***	5	82%	18%	-	6	100 %	-	-
A co-teaching approach will ensure that this unit is effectively differentiated.	0.070	5	68%	32%	-	6	88%	12%	-

† Frequency categories are compressed here (e.g., strongly agree and agree are combined), but were not compressed for data analysis.

†† One classroom teacher did not respond to this question.

Table 10: Comfort with and beliefs about co-teaching as reported in pre- and post-teaching surveys by classroom and enrichment teachers who co-taught (n = 29). 6-point Likert scale: Strongly Agree = 6, Agree = 5, Slightly Agree = 4, Slightly Disagree = 3, Disagree = 2, Strongly Disagree = 1. * = $p < 0.05$; H_{04} rejected.

	Wilcoxon Result	N matched pairs	Pre-teaching survey				Post-teaching survey			
			Median (/6)	Frequencies (%)†			Median (/6)	Frequencies (%)†		
				Agree or Strongly Agree	Slightly Agree or Slightly Disagree	Disagree or Strongly Disagree		Agree or Strongly Agree	Slightly Agree or Slightly Disagree	Disagree or Strongly Disagree
I feel comfortable co-teaching this unit.	0.317	29	5	90%	10%	-	6	90%	10%	-
I would feel (or would have felt) more comfortable teaching this unit alone.	0.677	29	2	14%	17%	69%	2	10%	21%	69%
I believe that this unit is most effectively taught using a co-taught approach.††	0.977	28	5	82%	14%	4%	6	75%	18%	7%
Student learning in this unit will be (or was) enhanced by having two teachers.	**0.011 ***	29	6	90%	10%	-	5	66%	24%	10%
A co-teaching approach will ensure (or ensured) that this unit is (or was) effectively differentiated.	**0.030 ***	29	5	76%	24%	-	5	62%	28%	10%

† Frequency categories are compressed here (e.g., strongly agree and agree are combined), but were not compressed for data analysis.

†† One classroom teacher who co-taught did not respond to this question.

Approaches to Co-Teaching

Teachers were asked to place a check mark next to any of the four co-teaching approaches they anticipated using for the STE unit in a multiple response question on the pre-teaching survey. Descriptions of each approach to co-teaching were provided on the survey for clarity. Of the 35 enrichment and classroom teachers who responded to this question, 66% anticipated using supportive co-teaching, 49% parallel, 57% complementary, and 66% team (H_{05} accepted). These percentages were not significantly different from one another, and there was no significant difference between enrichment and classroom teachers' anticipated co-teaching approaches (H_{06} accepted).

On the post-teaching survey, teachers were asked to indicate the frequency with which they used each type of co-teaching approach on a Likert scale (4 = exclusively, 3 = frequently, 2 = occasionally, and 1 = never) (Table 11). Classroom teachers who taught multiple classrooms of students were asked to answer this question with regard to the classroom in which they most frequently co-taught. Enrichment teachers were asked to consider frequency of co-teaching approaches across all teachers with whom they worked. Supportive ($p < 0.01$) and complementary ($p < 0.05$) approaches were reported to be used more frequently than either parallel or team approaches, thus rejecting H_{07} (Table 12).

Table 11: Median and frequency of use of co-teaching approaches by N = 34 teachers. 4-point Likert scale: (= exclusively, 3 = frequently, 2 = occasionally, and 1 = never.

	Median	Exclusively	Frequently	Occasionally	Never
Supportive	2	12%	26%	47%	15%
Parallel	1.5	0%	15%	35%	50%
Complementary	2	0%	26%	44%	29%
Team	2	0%	15%	38%	47%

Table 12: Significance of difference in frequencies of each approach to co-teaching across N = 34 teachers (8 enrichment teachers; 32 classroom teachers) using Wilcoxon Matched Pairs Signed Rank test. * = $p < 0.05$; ** = $p < 0.01$.

	Supportive	Parallel	Complementary	Team
Supportive	1.000	0.002**	0.068	0.006**
Parallel		1.000	0.022*	0.837
Complementary			1.000	0.041*
Team				1.000

After indicating how frequently they used each co-teaching approach, teachers were asked to identify factors that influenced the kinds of co-teaching approaches that they utilized (Table 13). They were provided a list of potential factors and asked to "check all that apply." A text box was provided for other factors not included in the list. As is evident in the table, the most frequently identified factors for both classroom teachers who co-taught and enrichment teachers: availability of the enrichment teacher, the nature of the lesson, and student needs.

These data suggest that more often, decisions to use particular co-teaching approaches happened "on the fly" rather than as a planned strategy. One teacher elaborated her indication that she and her co-teacher determined approaches "on the fly", stating that she and the enrichment teacher "have similar teaching styles and are comfortable adjusting our instruction as we teach."

Table 13: Factors that impacted the co-teaching approaches utilized by enrichment teachers and classroom teachers who co-taught (post-teaching survey).

Factor	% Classroom teachers who co-taught (n = 21)	% Enrichment teachers (n = 8)
Enrichment teacher availability	86%	100%
The nature of the activity/lesson	71%	88%
The needs of our students	52%	88%
We figured out what worked "on the fly" as we were teaching the unit in the classroom together	52%	75%
Classroom teacher personality/comfort level	33%	63%
Enrichment teacher expertise	33%	63%
We have worked together in the past, and this/these kind(s) of co-teaching worked for us	33%	50%
Classroom teacher expertise	33%	38%
Prior to instruction, we planned to engage in particular co-teaching approaches	29%	50%
Enrichment teacher personality/comfort level	29%	25%
Classroom teacher availability	10%	13%

Interview data support that supportive and complementary approaches were the most frequent kinds of co-teaching approaches utilized in the SySTEmic Project, and provided further description of what these approaches entailed. Very often, enrichment teachers supported the hands-on engineering design process lessons that were led by the classroom teachers. Jean said that her enrichment teacher would come in "if ... she felt like we needed an extra set of hands". On a testing day, Shannon "gave the overall direction," and the enrichment teacher "would go around and start questioning the kids." While most co-teaching pairs used supportive approaches with the classroom teacher as the lead (as was the case for Jean and Shannon), Karen shared that she and the enrichment teacher, Dana, took turns being in supportive role.

Some classroom teachers described their co-teaching relationships as being primarily supportive in nature, yet with occasional features of complementary relationships where the enrichment teacher would "chime in" (Angela) or make contributions when "teachable moments" (Heather) arose during the class. Other descriptions of complementary approaches during the STE unit included:

> "Whatever topic we were on, she would kind of throw out another real life example … she [enrichment teacher] wasn't afraid to just kind of throw something in there." (Becky)

> "She was also the one where we introduced the materials and let the kids kind of explore with them and we were kind of able to bounce back and forth our thoughts and model and think aloud for the kids." (Heather)

> "A lot of it was more I was teaching and she would interject. You know, for a lot of questioning or when she felt the need to expand on something or to clarify something." (Melanie)

Classroom teachers shared that enrichment teachers' knowledge of the STE units, expertise in asking higher order questions, and ability to extend learning beyond the unit content positioned them well to make useful interjections and ask good questions to push students' thinking. These important enrichment teacher contributions will be discussed further in the next section.

Parallel and team teaching were not elaborated as extensively in interviews as these co-teaching approaches did not occur very often. Parallel co-teaching experiences were highly dependent upon the nature of the lesson. Those STE unit lessons that involved simultaneous designing (by some children) and testing of designs (by others) lent themselves to parallel co-teaching (one co-teacher would help students with design while the other operated the testing apparatus). Also, some lessons within the 3rd and 4th grade units were co-taught by some teachers using stations, with one co-teacher operating each station. An STE unit storybook was read aloud by some co-teaching pairs in a parallel fashion, with the enrichment teacher reading the story to the students with higher reading levels.

Only one teacher recalled a team teaching episode from the STE unit during the interview. She and the enrichment teacher co-taught a PowerPoint® show on a science topic, sharing in a back-and-forth fashion the responsibility for teaching the content in that presentation. Others mentioned team teaching as an ideal co-teaching situation, but one that requires significant co-planning and thus substantial time to orchestrate. This sentiment is evident in Beth's response to a question during the interview:

> Author: You didn't have a true team teaching. Was that largely a scheduling thing?
>
> Beth: I mean it's mostly scheduling and planning … in order to do that well, [you have] to have the time to plan. And if you don't have the time to plan, then it's easiest to … just come and be a support person.

Thus, it's not surprising that supportive approaches were much more common than team approaches, especially given that co-planning was often challenged by scheduling issues. Complementary approaches also may not have required as much planning, especially given that enrichment teachers, like classroom teachers, received PD for the STE units. Jean explained: "She [the enrichment teacher] knew the unit so when we were testing and stuff she could interject comments to the children, [and] ask them questions … Even though we didn't plan together, she could come in and say, 'What are you doing?' And just jump right in."

According to some interviewees, co-teacher personality was another factor that dictated

not only overall willingness to co-teach, but the kinds of approaches to co-teaching taken up by the pair. Team and complementary teaching, in particular, require a good relationship, a degree of trust, and willingness let go of control (sometimes difficult for classroom teachers who are expected to be in control) to enact.

Enrichment Teacher Contributions

The final co-teaching items on the on the post-teaching survey asked teachers to consider the degree of importance of the roles that enrichment teachers can take on with regard to the SySTEmic Project with respect to two groups of classroom teachers: 1) teachers new to an STE unit (i.e., teaching it for the first time), and 2) "veteran" teachers who have already taught an STE unit (i.e., teaching an STE unit for the 2nd time or more). The list of roles from which enrichment and classroom teachers could choose was inclusive of all potential activities that the author had observed first hand or discussed with project leaders; further, an open-response text box was provided for "other" roles contributed by respondents (n = 34). No teachers added "other" roles, suggesting that the list was exhaustive. Table 14 provides medians and frequency data (where 5 = very important, 4 = important, 3 = moderately important, 2 = of little importance, and 1 = unimportant) with respect to both new and veteran teachers.

Overall and not surprisingly—when considering median responses and frequencies—enrichment teachers' roles were considered to be more important for teachers new to the unit than for teachers who have taught the unit in the past. In other words, generally speaking, enrichment teacher support is not as important for veteran teachers as it is for new teachers. These reductions in importance were statistically significant for six items, thus rejecting H_{08}: 1) setting up kit materials or testing apparatuses ($p < 0.001$); 2) discussing unit content ($p < 0.001$); 3) co-teaching unit lessons other than those that are hands-on-intensive ($p < 0.001$); 4) creating instructional materials (p , 0.001); 5) modeling instructional practices (e.g., higher order questioning) ($p < 0.005$); and 6) co-teaching hands-on-intensive lessons ($p < 0.01$) (Table 14). There was no statistically significant difference between enrichment teachers' and classroom teachers' assessment of importance for any enrichment teacher role with respect to either teachers new to the unit or veteran teachers (H_{09} accepted).

For both teachers new to the STE units and veteran STE unit teachers, the most important role that enrichment teachers can assume (based on highest mean, median, and frequency of "very important and important" responses) is: co-teaching hands-on-intensive lessons. This item was statistically more important ($p < 0.05$) than all but three items (i.e., setting up kit materials or testing apparatuses, modeling instructional practices, and discussing unit content) for new teachers. Co-teaching hands-on-intensive lessons was statistically more important ($p < 0.005$) than all but two items (i.e., differentiating instruction for all students, and modeling instructional practices) for veteran teachers. This analysis resulted in a rejection of H_{10} and the identification of two sets of the most important enrichment teacher roles: one for teachers new to the STE unit and one for veteran teachers (Table 15). Each set includes the enrichment teacher role deemed most important (co-teaching hands-on intensive lessons), as well as the other roles that are not statistically different in level of importance than this most important role.

Table 14: Importance of enrichment teachers' roles for teachers new to an STE unit and for "veteran" STE unit teachers (n = 34 teachers). 5-point Likert scale: Very Important = 5, Important = 4, Moderately Important = 3, Of Little Importance = 2, Unimportant = 1. * = $p < 0.05$, ** = $p < 0.01$, *** $p < 0.005$, **** $p < 0.001$; H_{08} rejected.

	Wilcoxon Result	Importance for Teachers New to Unit				Importance for "Veteran" Teachers			
		Median (/5)	Frequencies (%)†			Median (/5)	Frequencies (%)†		
			Very Important or Important	Somewhat Important	Of Little Importance or Unimportant		Very Important or Important	Somewhat Important	Of Little Importance or Unimportant
Co-teaching hands-on-intensive lessons	0.007 **	5	94%	-	6%	5	85%	9%	6%
Setting up kit materials or testing apparatuses	0.000 ****	5	76%	24%	-	4	59%	32%	9%
Modeling instructional practices	0.003 ***	5	88%	6%	6%	4	74%	18%	9%
Differentiating instruction for all students	0.377	5	79%	15%	6%	4	76%	18%	6%
Discussing unit content	0.000 ****	4	82%	12%	6%	3	29%	41%	29%
Creating instructional materials	0.005 ***	4	74%	18%	9%	4	56%	35%	9%
Creating content extensions to benefit the entire class	0.154	4	74%	18%	9%	4	62%	32%	6%
Creating extensions connected to the unit for small groups of students	0.377	4	62%	26%	12%	4	62%	26%	12%
Co-teaching unit lessons other than those that are hands-on-intensive	0.001 ****	4	59%	32%	9%	3	41%	35%	24%
Integrating unit content with content in other areas	0.234	4	53%	35%	12%	3	47%	41%	12%
Writing/editing unit assessments	0.017 *	4	56%	15%	29%	3	35%	29%	35%

† Frequency categories are compressed here (e.g., very important and important are combined), but were not compressed for data analysis.

Table 15: Most important enrichment teacher roles as they benefit teachers new to an STE unit and "veteran" STE unit teachers.

Most Important Enrichment Teacher Roles for Teachers New to the STE Unit	Most Important Enrichment Teacher Roles for "Veteran" Teachers of the STE Unit
• Co-teaching hands-on-intensive lessons • Setting up kit materials or testing apparatuses • Modeling instructional practices • Discussing unit content	• Co-teaching hands-on-intensive lessons • Modeling instructional practices • Differentiating instruction for all students

Interviewees echoed the importance of the enrichment teachers being available to co-teach hands-on lessons, especially engineering design process lessons during which children are designing, building and testing their first and then their improved designed. Often during these activities, design and construction occur concurrently. Depending on how the teacher(s) manage the engineering design process lesson, some children may also be testing while others are designing and building. These simultaneous activities require that teachers facilitate the development of children's ideas (e.g., how to use prior knowledge to design a solution to a problem) and manage materials. Some teachers saw the need for help by another teacher in the classroom as being primarily about materials management (e.g., to replenish materials, or to run a testing apparatus). Melanie, for example, felt that she wished she received more help during the hands-on-intensive lessons because she "would have rather been more involved in getting inside of their head and see what they were thinking … instead of being the runner and, you know, getting things for them." Indeed, this is what some classroom teachers did with the help of special educators, student teachers, and paraprofessionals, especially when enrichment teachers were not available for support.

However, many preferred the assistance of the enrichment teachers who were trained in the STE units. These professionals understood the likely pitfalls of the design process, the questions that students need to be asked about their testing results, and the ways to guide students towards an improved design. Nancy, an enrichment teacher, explained:

> It's beneficial to have two people in there to go around as children are creating and just asking questions to get the kids thinking more about what they are doing. You know, it's hard for one teacher to do that. And kids aren't going to think things through … but you can ask them those questions that will make them think. Not giving them answers, but you know—What properties does this material have that makes you think it will catch the wind?—or whatever. (Nancy).

This speaks to an element of enrichment teacher expertise—asking higher order questions—that is quite appropriate for helping students engage in the engineering design process. The following exchange between the author and Julie, a classroom teacher, captures this well:

Author: And what is it about the enrichment teacher being in there with you to co-teach … as compared to say an aide or something, or a parent?

Julie: That's true.

Author: What do they bring that make that co-teaching experience better, if at all?

Julie: Because I think a parent might take over. I think an aide might not have the background knowledge … Paula's really good at just saying a phrase or a question to a kid, not giving them the answer, but just making them stop and think about what could you do differently … She's really good at … leading them to a new way of thinking … knowing that kid and knowing that if [she] asked this question they are going to figure it out on their own ... she has that background.

The questioning strategies to which Julie, Nancy and others referred were the primary instructional practices that enrichment teachers modeled for classroom teachers (i.e., in the role, "Modeling instructional practices") that were discussed in the interviews. The following exchange with Becky, a classroom teacher, exemplifies this:

Author: Would she be controlling the testing station and you would be somewhere else?

Becky: Right, right. I mean she took over. Like, she would ask them the questions. Well why do you think that it's not working? … Which was good for me because as she was saying that I'm like I need to be asking those too. But she you know, that was kind of her focus. So she could kind of remember to do those sorts of things. When I was by myself, I know we finished up the next day I would remember okay, let's make sure I am asking these questions.

Heather mentioned that Donna, the enrichment teacher, video-recorded her interview-like discussions with students where she would ask the students "What is your design? Why did you do that?" Heather would review the video, and then would ask the same questions of students during subsequent days of instruction. Katie recalled listening to the enrichment teacher who asked a question that Katie was going to ask, but "the way that she [the enrichment teacher] asked it was exactly how it should have been and really pulled this kid to be able to explain it."

For these teachers and others who described similar events, modeling questioning practices for classroom teachers seemed like a natural consequence of the enrichment teacher being in the room during the engineering design process lessons and 'doing her thing' (as Beth, an enrichment teacher, offered: "my job should be asking those questions"). Although this was not a case of direct instruction by the enrichment teacher to the classroom teacher with regard to asking good questions, the need to ask good questions can be an explicit part of co-planning. Nancy, an enrichment teacher, shared that it's "just not possible" to co-teach all engineering design process lessons with all classroom teachers at her school, yet co-planning can involve "two minds thinking of questions" to "get kids thinking."

Many classroom teachers mentioned the important help of enrichment teachers to prepare materials and testing apparatuses. This is somewhat akin to enrichment teachers helping with hands-on aspects of the STE units for purely hands-on reasons. However, this did seem to help the classroom teachers with the materials-heavy nature of implementing engineering instruction.

Katie described the materials preparation support by the enrichment teacher as "a huge help" given that the "whole EiE prep was enormous." When scheduling conflicts made co-teaching less possible, enrichment teachers did what they could to prepare materials for classroom teachers, including instructional materials like PowerPoint® presentations. In one school, testing apparatuses were housed in the enrichment teachers' classroom, a portable outside of an otherwise open-classroom school (i.e., in which there are few walls between classrooms). Classes would come to the enrichment teacher's room to build and test designs, and could be freely louder and more active than they could be in their home classrooms. In this and other ways, enrichment teachers helped with local needs and to provide a sort of triage to smooth the relatively heavy materials preparation demands for the first year of implementing the STE unit. Such help was considered to be a sort of "bonus" to some—a helpful, but not necessary task for enrichment teachers to take on. For example, Scott, a classroom teacher, explained that he can take care of materials preparation; what was more important was that on days in which he would co-teach, both teachers in the room would know how to use those materials.

Enrichment teachers provided a means of differentiating instruction, particularly for children who were ready to answer higher order questions. Scott said that Nancy helped to differentiate for "our gifted kids." Katie, a classroom teacher, shared that the enrichment teacher with whom she worked helped her to differentiate instruction for the entire class:

> Where I really have to focus on this group over here because they are really needy, she could have … gone [to a] higher level of thinking with a few other ones. Like just that kind of realm of: an enrichment teacher helps. (Katie)

Similar to Nancy's insight about discussing questioning techniques during co-planning with classroom teachers, Paula shared that even if she cannot co-teach with the classroom teachers at her school, co-planning can involve a discussion of how to help all learners engage appropriately in the essential understandings of the unit through differentiation.

Although deemed important in the post-teaching survey data, teachers did not talk extensively in interviews about discussing unit content with enrichment teachers. Enrichment teachers were regarded as having content knowledge including but beyond the STE unit content, enabling them to "make connections to other areas of the curriculum" (Theresa). Heather described the enrichment teacher at her school as "more of a science buff" with "more of an interest and background in science" than she did. Denise, a classroom teacher shared that perhaps the need for content support by the enrichment teacher was not as great for her because of the extensive professional development that she received in the SySTEmic Project.

Beyond the most important enrichment teacher roles described in Table 15, interviews provided insight regarding other important roles that enrichment teachers took on during the pilot year. Enrichment teachers working with multiple classroom teachers within one grade level were able to share practical knowledge about the unit across teachers. For example, Becky shared that the enrichment teacher had already co-taught with another teacher, and thus understood the flow of the lessons well and could suggest to her how much time lessons would actually take. Similar practical knowledge about teaching the units was also shared between same-grade-level classroom teachers at some schools. Finally, some classroom and enrichment teachers discussed

the importance of enrichment teachers creating STE unit extensions for whole class instruction or for small groups of students (also included in Table 14). Such extensions were not created during the busy pilot year, yet this is a role that was described as one that is appropriate for enrichment teachers to take on in the future with regard to the STE units.

Discussion

This study has provided a way to examine classroom/enrichment co-teaching as a means to support classroom teachers as they engaged in their first engineering teaching experience within STE units. Although co-teaching was not as a panacea for all challenges that classroom teachers experienced as they taught the units—nor was co-teaching positioned this way when introduced to SySTEmic Project teachers—most teachers ultimately perceived co-teaching to be helpful, benefitting both teaching and learning.

It is likely that some of the descriptions of co-teaching by SySTEmic Project participants—especially those where hands-on support or materials preparation by the enrichment teacher was the primary type of support—may not be regarded as legitimate by co-teaching advocates. [8-10] Co-teachers, according to these advocates, should not be relegated to a status of handing out papers or supplies or setting up background equipment. Although this is a worthy argument, it behooves co-teaching advocates and engineering educators to consider that the hands-on aspects of engineering design process instruction are coupled with "minds-on" activity. Hands-on-intensive activity during the engineering design process involves simultaneous use of reasoning and other skills by students, and thus, those enrichment teachers who co-teach during these times are likely to facilitate idea development in the course of being helpful with materials management or running the test apparatus. What may have been most memorable for some classroom teachers was that they survived teaching the active, messy, materials-intensive design process with the help of an "extra pair of hands." What happened in many cases as reported by classroom and enrichment teachers, and may have happened in classrooms in which the classroom teacher was too occupied to notice, was that the enrichment teacher was much more than an extra body in the classroom. (This argument, however, does not intend to delegitimize the experiences of some classroom teachers who may not have received the full benefit of enrichment teachers' questioning strategies.)

There are practical implications to be made from investigating co-teaching during the SySTEmic Project's pilot year. Specifically, an answer to the question, "How should co-teaching proceed for the SySTEmic Project?", can be suggested. As was the case in the beginning of the project, co-teaching cannot be mandated, yet enrichment teacher participation can be made more focused and realistic given some of the strengths of and barriers to co-teaching addressed throughout this paper. The most essential co-teaching roles that enrichment teachers can make to assist with future SySTEmic Project implementation, based on the findings of this study, are as follows:

- **Co-planning the engineering design process lesson** in each STE unit with classroom teachers, which includes discussions of higher order questions relevant to the lesson, ways to "push" students' thinking, and—if co-teaching—the approach(es) (i.e., supportive, parallel, complementary, or team) appropriate for the lesson.

- **Co-teaching the engineering design process lesson**, providing a combination of hands-on support and the facilitation of idea development through questioning strategies.

These roles capitalize on enrichment teachers' unique strengths, are likely to benefit student learning (although this was not assessed in this study), and will support teachers—especially teachers new to the STE units, but also veteran STE unit teachers—as they implement the STE units. Note that the co-teaching focus is on the engineering design process *lesson*, rather than on co-teaching the STE *unit*. Even for the pilot year, it was impossible for most enrichment teachers to find time in their schedules to co-teach even half of the lessons in each unit. This challenge will escalate as the project grows. Project growth will continue until 2012-2013 when all district elementary teachers (about 700 across 33 schools) will teach an STE unit at her/his grade level; the number of enrichment teachers will also grow, yet will maximize at approximately 33 (one per school). Perhaps even the above roles are optimistic with regard to the demands placed on enrichment teachers.

Certainly, beyond these contributions, enrichment teachers may choose to contribute in other ways. They may co-teach and co-plan more lessons within the unit as time allows. They may develop extension activities for the STE units as they do for other curricular areas, providing added benefit to the classroom beyond basic support of STE unit implementation. Additionally, other strategies and individuals may be able to fill the other roles that enrichment teachers took on during the pilot year or that were deemed important by pilot year teachers (Table 14). For example: the EiE project has made available instructional videos to assist classroom teachers with how to set up testing apparatuses; parents or paraprofessionals may be enacted to help prepare materials; district leaders can facilitate the development and sharing of assessments and other instructional materials as they have done for other instructional units; and special educators can co-teach with classroom teachers in inclusive classrooms (as was this case in some classrooms during the pilot year).

Two caveats: Even after paring down the co-teaching roles for enrichment teachers to the essential roles, above, not all barriers to co-teaching can be overcome. Some schedules may never be able to accommodate co-teaching, and those not interested in co-teaching cannot be forced to co-teach. Also, these essential roles have been suggested via analysis of data from pilot year SySTEmic Project teachers. These teachers volunteered to participate. Subsequent years of implementation will undoubtedly include a more diverse subset of teachers with broader ranging perspectives about co-teaching and elementary engineering instruction. In many respects, the pilot year was a "best case scenario" for co-teaching, representing the fewest number of classroom teachers with whom enrichment teachers would work, and who are likely to be some of the most receptive teachers to teaching the STE units.

It may be unique to the district in which the SySTEmic Project operates for enrichment teachers to be the primary co-teachers with classroom teachers for engineering instruction. Other districts may have STEM specialists or others who can provide a similar co-teaching role, offering teachers both hands-on and pedagogical support as students engage meaningfully in the engineering design process.

In the future, it would be useful to extend this research to investigate the impact of co-teaching on student learning—an area of co-teaching research that is understudied. Specifically, it would be interesting to answer the question: Might students in classrooms co-taught with enrichment teachers have a better understanding of the engineering design process or develop more reasoned designs?

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