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ORIGINAL ARTICLE

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Engineering integration in elementary science classrooms: Effects of disciplinary language scaffolds on English learners' content learning and engineering identity

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Abstract

Background: Limited research examines the effects of integrated science and engineering (SE) instruction emphasizing disciplinary literacy and language activities on engineering identity and content understanding. Far fewer studies target English learners (ELs).

Purpose: The impact of an SE intervention on the development of science, engineering, and technology knowledge as well as engineering identity was examined. To address ELs' learning needs, the curricular design was built on a validated SE model by integrating (1) developmental, (2) language scaffolds, and (3) culturally based accommodations.

Design/Method: Separate analysis of variance examined the effects of the intervention on science, engineering, and technology knowledge as well as engineering identity. The relationship among engineering identity and content outcomes was also examined. ELs from kindergarten to second grade classrooms were randomly assigned to the integrated SE group or control group.

Results: Integrated SE instruction significantly increased ELs' science, engineering, and technology knowledge as well as a substantially developed engineering identity. Overall, ELs' engineering identity is associated with an increase in science, engineering, and technology content knowledge. However, second grade girls' identity development was not associated with learning measures. These correlations suggest the context of the engineering activity may have reinforced gendered stereotypes and reduced the effects for girls' engineering attitudes.

Conclusions: Integrated SE instruction emphasizing disciplinary literacy and cultural accommodations increases early elementary ELs' learning and engineering identity. Future studies should examine the unique effects of language scaffolds and cultural modifications on student learning and the impact of gender stereotypes on girls' engineering attitudes.

KEYWORDS
elementary school, engineering curriculum, English learners, identity, instruction, student diversity

1 | INTRODUCTION

Engineering solutions to increasingly complex grand challenges remain an ever-pressing global concern. As the complexity of grand challenges increases, so do the knowledge bases that inform the work of engineers. For example, problem-solving is becoming increasingly multidisciplinary, and the lines between science and technology are blurring (National Academy of Engineering [NAE], 2005). This shift draws attention for the need to integrate science and engineering (SE) instruction. Further, SE instruction should involve authentic technology design experiences because engineering by definition involves the application of multiple sciences in the development of technologies that solve a problem or benefit society (Aguirre-Muñoz & Pantoya, 2016). Since engineering involves the development of technologies (Massachusetts Department of Education, 2001), explicit authentic instruction of technology is important to teach English learners (ELs).

In this context, recent reform policies in the United States call for the integration of engineering and technology focused on real-world practice into science education in K-12 classrooms. Despite the increased visibility of engineering content in K-12 education reflected in the Next Generation Science Standards (NGSS; National Research Council [NRC], 2008; Carr et al., 2012), there remains limited research on effective engineering education practices for early primary students. Early childhood education experts maintain that very young children can and should be acquiring knowledge that provides the foundations for subsequent science, technology, engineering, and mathematics (STEM) learning (NRC, 2008). Yet, the great majority of engineering education research targets secondary and postsecondary students (Aguirre-Muñoz & Pando, in press; Aguirre-Muñoz & Pantoya, 2016). Fewer studies target the impacts of SE instruction on learning outcomes of primary school ELs. We argue that EL instruction requires the use of both language scaffolds—language-based supports provided to students to enhance learning and aid in the mastery of tasks—and cultural accommodations to enable ELs to benefit from learning opportunities (Aguirre-Muñoz & Amabisca, 2010). The purpose of this study was to examine (1) the impact of an integrated SE unit with language scaffolds and cultural accommodations on science, technology, and engineering knowledge of ELs; (2) the impact of SE instruction with accompanying language scaffolds and cultural accommodations on engineering identity development; and (3) the relationship among content learning, gender, and grade level.

Although there is increasing interest in engineering education research, few studies focus on developing strategies designed for the learning needs of ELs. Past studies have shown that SE integration can lead to increases in science learning (e.g., Wendell & Rogers, 2013), attitudes (e.g., Cunningham & Lachapelle, 2014), and interest (e.g., Guzey, Harwell, et al., 2016). However, these studies did not include samples of students who required additional language learning needs. Therefore, little is known about the types of teaching strategies and scaffolds that enable ELs to benefit from SE instruction. This study fills a gap addressing teaching strategies that benefit ELs by investigating the degree to which integrated SE instruction with language scaffolds and cultural accommodations enhances science and technology knowledge as well as promotes positive engineering identity development. Thus, the general aim was to examine whether ELs benefit from SE instruction designed to meet their language learning needs by utilizing culturally relevant material. Since our sample comprised ELs with predominately beginning and intermediate levels of English proficiency, it was necessary to provide language scaffolds to ensure ELs benefit from instruction to comply with state and federal policy. Thus, the intent was to examine the impact of the SE instruction for young ELs with low English proficiency and not to test the added value of specific language scaffolds on ELs' outcomes.

2 | LITERATURE REVIEW

2.1 | SE integration research

There is a wide variety of SE integration approaches (also referred to as engineering design-based science instruction) currently available (e.g., Fortus et al., 2004; Guzey et al., 2014). Common among them is the inclusion of activities that engage students in the engineering design process (EDP). In the EDP, students identify problems and engage in problem-solving (Brophy et al., 2008; NAE & NRC, 2014). For example, Wendell and Rogers (2013) developed a year-long integrated SE curriculum involving several units where third and fourth grade students learned how to build prototypes, complete scientific investigations, and solve a design challenge. Students in the SE instructional group outperformed the control group on measures of science content knowledge. Similarly, Yoon et al. (2014) used *Engineering is Elementary* units (EiE: Cunningham, 2005) and project-developed units to test the impact of SE integrated curricula on second to fourth grade ethnically diverse students' science knowledge and engineering identity development. Students receiving the integrated SE instruction performed significantly higher than the control groups on knowledge tests in all three grade levels. The SE instruction groups at all three grade levels also had higher engineering identity by the end of the intervention. The results from this study indicate that integrated SE instruction can have positive effects on student learning and identity development. Yoon et al. (2014, p. 388) maintain that intervention students had a greater understanding of the work of engineers and "were able to identify with some of these roles (e.g., design things)." The positive learning outcomes reported suggest engineering design tasks provide the context for young learners to envision themselves as future engineers.

In another study involving EL kindergarten female students, Aguirre-Muñoz and Pantoya (2016) used an adapted EiE unit targeting agricultural engineering to study the effect of engineering-centered literature and academic conversations (a language scaffolding strategy) to enhance linguistically diverse students' engagement with SE content. Using a single-case design methodology, three types of engagement were measured: behavioral, affective, and cognitive engagement. Results relevant to the current study are related to cognitive engagement—a child's appropriate use of SE vocabulary, persistence in completing tasks, and resistance to distractions. The engagement trends showed clear evidence of a functional relationship between the integrated SE instruction and cognitive engagement. This finding was replicated across classrooms and ability levels suggesting young ELs can benefit from integrated SE instruction with language scaffolds.

However, other research reveals that the impact on science learning is not uniform across content topics and groups of students. For instance, in a large-scale, quasi-experimental study, Guzey et al. (2017) found positive effects for middle school learning of physical science (heat transfer) but no significant effects for elementary school (fourth and fifth grade) science learning. Further, achievement disparities persisted, advantaging Anglo-American students, despite the integrated SE instruction. Guzey et al. (2017) also found a significant relationship between quality of SE integration and student outcomes. They concluded that low integration quality largely contributed to the lack of impact on student outcomes. The authors also acknowledged that the lack of instructional scaffolds for diverse learners likely contributed to group disparities.

ELs require concrete experiences to articulate ideas, and our prior work demonstrates how ELs mediate this experience through language (Aguirre-Muñoz et al., 2018; Aguirre-Muñoz & Gregory, 2019). Thus, proficient English speakers and students with larger language repertoires have an advantage in benefiting from integrated SE instruction (Greenleaf et al., 2011). Therefore, focusing instruction on language practice is a necessary scaffold for learning opportunities to be equitable for all students and accessible to young ELs (Aguirre-Muñoz, 2014a, 2014b; Aguirre-Muñoz & Amabisca, 2010).

2.2 | Disciplinary literacy development

Making SE accessible to ELs is a complex process that should involve promoting disciplinary literacy. Disciplinary literacy refers to knowledge and abilities possessed by those who create, communicate, construct, and apply knowledge within a discipline as well as the use of tools by experts to participate in the work of that discipline (Shanahan & Shanahan, 2012). Thus, SE disciplinary literacy refers to both *language and practice* to produce knowledge (S. Hall, 2001) and stems from the understanding of SE as social and cultural practices (Osborne, 2014; Samarapungavan et al., 2008). Social and cultural practices require using language to articulate ideas. For example, in science, ideas lead to reliable knowledge through the process of critique, a language practice (Ford, 2008). This process also leads to better understanding for students. A number of studies have found engaging in the social practice of critique leads to enhanced conceptual knowledge (e.g., Hynd & Alvermann, 1986; Schwarz et al., 2000). Yet, there is an absence of critique (as well as focused disciplinary language practice) in most science classrooms (Osborne, 2014). Thus, we argue that a focus on disciplinary literacy is necessary for promoting ELs' disciplinary language use in the context of disciplinary practices. For ELs, engaging in disciplinary language use through SE instruction requires using and producing language in new ways, specifically in communicating scientific observations, reasoning about relationships, explaining abstract concepts and ideas, and making scientific arguments (J. P. Gee, 2005; Osborne, 2014). In EL instructional contexts, these experiences require carefully designed scaffolds informed by meaning-based theories of language use (Aguirre-Muñoz, 2014b) such as systemic functional linguistics (SFL; Halliday, 1975).

2.2.1 | Systemic functional linguistics

The SFL theoretical framework further informs our disciplinary literacy perspective. SFL researchers examine text and genre from the global view and support how disciplinary actors take up appropriate linguistic resources and use them for the given genre and (disciplinary) context. Within the SFL perspective, meaning is expressed through clauses and their component parts (noun groups, verb groups, and adverbials). These clauses form clause complexes that actualize the logical function. Discourse patterns of a community of practice evolve from the values and attitudes of a community reflecting discipline-based habits of mind and are integral for engaging in the community following disciplinary norms (Aguirre-Muñoz & Pando, in press). SFL theory describes the linguistic mechanisms (field, mode, and tenor contextual variables of language use) at play in the outward manifestations of disciplinary discourse communities' habits of mind including values and attitudes. See Table 1 for a description of these variables and some key linguistic features for SE contexts. The logical structures of Western science, for example, have specific linguistic patterns pertaining to reasoning, argumentation, questioning, and critique among others (Fang, 2005; Fang & Schleppegrell, 2008; Schleppegrell, 2004). The logical structures from these genres reflect interactional styles that can be made explicit for ELs utilizing the language mechanisms identified in SFL descriptions of language use. Together, contextual variables (field, tenor, and mode) generate the language register for sense-making in STEM (Aguirre-Muñoz & Pando, in press). The language scaffolds utilized in the SE intervention targeted two of these linguistic dimensions (field and tenor).

2.2.2 | SE discourse patterns

Disciplinary literacy informed by SFL argues that SE discourse patterns (e.g., forming a hypothesis, making an evidence-based argument) are different from everyday language (Schleppegrell, 2004). Linguistic theorists have suggested that even speakers who are English native speakers must recognize SE discourse as a type of English language (Halliday & Martin, 1993). The assumption this perspective takes is that disciplinary discourse supports developing higher levels of disciplinary knowledge and practices that reflect closer approximations of disciplinary norms. Thus, whether their first language is English or not, to engage in SE discourse, students must be taught to learn the discourse of SE disciplines (e.g., Fang & Schleppegrell, 2008; Fang & Wei, 2010). Learning disciplinary discourse patterns, however, involves more than integrating general literacy activities in inquiry or project-based lessons as others have done (e.g., O. Lee et al., 2016; Llosa et al., 2016; Maerten-Rivera et al., 2016; Tong et al., 2014). For example, in the study conducted by Llosa et al. (2016), there was no explicit instruction on relevant science genres (scientific description and/or explanation) in ways that scaffolded conceptual understanding or reasoning. Not surprisingly, students who most benefited from science instruction were monolingual English students and ELs redesignated as English proficient.

TABLE 1 Linguistic mechanisms for articulation of habits of mind within communities of practice in science and engineering

Mechanism[a]	Description/features
Experiential/ ideational: Field	Refers to how language is used for expressing and connecting ideas for specific genres (e.g., explanation, argument) and contexts (classroom discussion with peers, student–teacher interactions) *Key linguistic features* (a) Complex noun groups with specialized, technical, and abstract vocabulary (b) Verbs that enable clause-internal reasoning with nouns, verbs, and prepositions instead of conjunctions
Interpersonal: Tenor	Refers to how language is used to communicate to enact interpersonal relations and to establish authority *Key linguistic features* (a) Declarative mood and modal verbs to accomplish "reasoned" judgments (b) Implicit evaluation construction ("It seems that instead of 'I think that'")
Textual: Mode	Refers to how language is organized into cohesive and organized texts for specific genres *Key linguistic features* (a) Clause-combining strategies of condensation and embedding (subordinate clauses) (b) Lexically dense clauses through the use of abstract nouns that express a whole clause of information (grammatical metaphor/nominalization)

Note: Each contextual feature described has multiple strategies for accomplishing linguistic expectations.
[a]Systemic functional linguistics refers to these mechanisms as linguistic metafunctions.

2.2.3 | Scaffolding disciplinary discourse

The differential effects of language background described in the study conducted by Llosa et al. (2016) and the differential effects of race described in the study by Guzey et al. (2017) may be attributed to the need for more targeted scaffolding of disciplinary discourse such as explanation and argumentation. As Mercer et al. (2004) have found, engaging in explanation and argumentation improves conceptual understanding. These texts include reasoning components that when put into practice through language use for constructing or comprehending require articulation and critique of ideas fostering conceptual understanding. To develop conceptual understanding, targeted scaffolding in disciplinary discourse should include explicit discourse strategies to understand one another while working toward a particular goal (e.g., test materials, construct an efficient design) (Tang, 2021). By definition, scaffolding in interaction "mediates learning, supporting, and promoting it" (Walqui, 2019, p. 188). In other words, effective scaffolds do not take away from content learning; they amplify learning by promoting learner agency and control of actions (Walqui & van Lier, 2010). In addition, bridging—connecting students personally to the theme (Walqui, 2019)—was achieved with the cultural adaptations to the engineering challenges to stimulate interest and engagement. Thus, language scaffolds targeting disciplinary discourse (including structural and process routines) and cultural accommodations were integrated to ensure productive engagement of ELs' in SE instruction. The assumption we make is that both the language scaffolds and the cultural accommodations together promote productive engagement, which leads to increased performance and, in turn, contributes to students' engineering identity.

2.3 | Engineering identity development

Identity development has been well documented in STEM-related disciplines, including (1) middle and high school science (e.g., Andree & Hanson, 2013; Brickhouse & Potter, 2001) and (2) undergraduate mathematics (e.g., Boaler & Greeno, 2000), technology (e.g., C. Hall et al., 2011), and (3) engineering education (e.g., Capobianco, 2006; Tonso, 2006). Similarly, engineering identity—defined as how one comes to view themselves as the kind of person who could be an engineer (Capobianco, 2006)—contributes in significant ways to a student's ability to persist in challenging STEM tasks and content courses as well as major in and complete postsecondary degrees in these fields (Capobianco et al., 2012). Therefore, if the learning context reinforces accurate conceptions of engineering and engaging design activities, it can support the development of positive engineering identity (M. Pantoya et al., 2015). Capobianco et al. (2017), for example, provided third through sixth grade teachers with an intensive summer institute where they developed a series of multiweek integrated SE units. These units were implemented over the course of 1 year. Results indicated growth in engineering identity for all students after the first integrated SE unit. Thus, Capobianco et al. (2017) and others (e.g., Capobianco et al., 2012; Douglas et al., 2014) show engineering identity development is important to study because early conceptions of engineering can provide important information that assists STEM educators in designing curricula that engage elementary students in activities that can transform their identity using STEM content.

2.3.1 | Language and identity development

However, few studies have examined engineering in primary students (Capobianco et al., 2017). Early identity development is also important because a student's academic identity is strongly associated with the types of goals a student will adopt, which, in turn, affect the types of strategies and behaviors the student exhibits in an academic setting (e.g., Capobianco et al., 2015; Godwin et al., 2013; Hazari et al., 2010; Was et al., 2009). Nevertheless, for students to develop a positive identity in academic areas, including engineering, a focus on social interaction during academic work is needed. Such activity affords students opportunities to produce and practice disciplinary literacy (Aguirre-Muñoz et al., 2020; Mercer, 2000, 2008; Walqui, 2019; Zwiers & Crawford, 2011). We maintain this practice is essential for enabling ELs' contributions to the production of knowledge during collaborative disciplinary literacy activity that, in turn, promotes a positive engineering identity. That is, the language students' use in SE interactions can contribute to and reinforce identity development, particularly for minoritized students (Brown, 2004).

For example, Reveles et al. (2004) documented the power of communication and participation during science investigations that contribute to academic identity and scientific literacy. In a follow-up study (Reveles et al., 2007), results reinforced the importance of the collective practice of scientific conversations and activities as driving both broad disciplinary literacy skills and positive science identity. These studies suggest language and activity influence academic identity formation. Further, Capobianco et al. (2012) summarized the role of language in relation to learning and disciplinary identity in the following, "students' communication and participation in science [and engineering] enable them to learn the structure of the discipline and, furthermore, contribute to the formation of their science [and engineering] identities" (p. 701).

Focusing on learning language structures of disciplines in multilingual and multicultural context requires scaffolds that encourage the use of ELs' language and cultural resources for sense-making in integrated SE instruction. However, applying rigid expectations of the use of disciplinary language and practices would limit, not promote, the type of language use that supports positive identity development. Since identity formation is enhanced when students are active in co-construction of knowledge (Reveles et al., 2007), rigid expectations would make it difficult for ELs to engage in classroom activity that promotes identity formation. Thus, for culturally and linguistically diverse students, instructional supports are needed to facilitate explicit but *flexible* integration into disciplinary norms for communication and participation. Our disciplinary literacy approach described above aligns with this learning need for ELs.

Activities designed with scaffolding strategies aligned with developmental and language learning needs have shown to promote ELs' use of SE disciplinary language as they engage in a literacy-rich, integrated SE intervention (Aguirre-Muñoz et al., 2020). For example, Aguirre-Muñoz et al. (2018) analyzed oral production of kindergarten to second grade ELs over the course of two integrated SE units. Data trends demonstrated that ELs' use of linguistic structures to paraphrase, "build on" others' ideas, and challenge/reason improved over time and approximated SE disciplinary practices. This study showed that young ELs could develop disciplinary literacy skills leading to reasoning about evidence and design constraints when provided with meaningful and scaffolded, hands-on opportunities as they solve engineering problems. Identity development was not directly examined; however, students' language patterns and interactional styles corresponded with the kinds of language use and disciplinary practices associated with individuals who view themselves as being able to do the work of an engineer.

Thus, the second aim of this study was to investigate the impact of SE instruction with accompanying scaffolds and cultural accommodations on engineering identity development (Bransford et al., 2000). The design characteristics of these modifications are informed by past research and theory linking their use to improved student learning and identity development. From a cognitive priming model of learning (see Figure 1), *scaffolded* tasks are important because they can increase attention to engineering practices, which can lead to cultivating interest over time. Multiple opportunities over time are more likely to produce this effect, and the accumulation of goal-directed activities (e.g., engaging in the EDP, after school activities, summer camps, etc.) supports increased engineering behaviors (e.g., persistence on challenging design tasks) (Ainley & Ainley, 2015). Supportive experiences (e.g., language scaffolds and cultural accommodations) in authentic engineering behaviors, in turn, maintain sustained interest in engineering (Dunlap, 2005; Lentz & Boe, 2004). Interest in engineering then leads to enrollment in courses in middle and high school (Maltese & Harsh, 2015; Ricks, 2006) and reinforces their identity as engineers and nurtures their pathway to an engineering career (Roselli & Brophy, 2006).

We argue that tasks without appropriate scaffolds and cultural accommodations do not provide the early cognitive priming necessary to promote growth in identity development. Thus, the third aim of the study was to examine the relationship among gender, grade level, SE learning outcomes, and engineering identity. Such analyses would provide needed information about the age at which SE learning outcomes correlate with engineering identity. In addition, changes in the strength and direction of the relationships would shed light on the stability of the relationships across grades and gender.

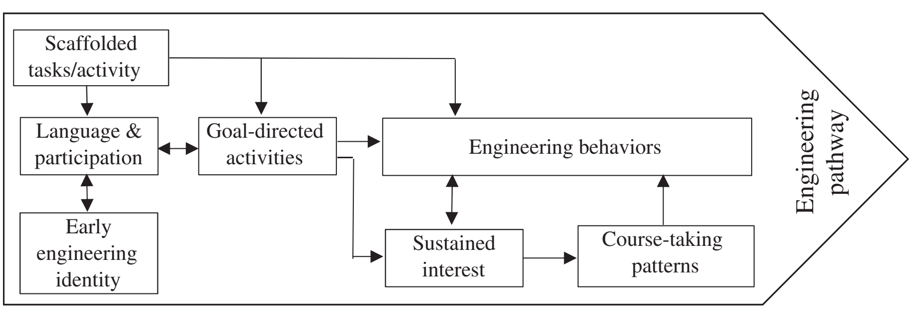

FIGURE 1 Cognitive priming model of learning. This model demonstrates the role of scaffolded tasks/activities, language, and participation in the early development of engineering identity in relation to goal-directed activities and engineering behaviors

2.4 | Context of the study curriculum

2.4.1 | Evidence-based units

The unit, an adaptation of an EiE unit (Cunningham, 2005), involved integrated SE activities lasting six to seven days. The unit targets sound and acoustical engineering that fit well into the fall science curriculum scope and sequence of the participating school. Further, the unit addressed science content that was developmentally appropriate for the kindergarten through second grade students: (a) matter and energy and (b) force, motion, and energy. The curricular units provide a research-based strategy for integrating engineering content into science instruction (e.g., Cunningham et al., 2005; Cunningham, 2009; Cunningham & Lachapelle, 2014). However, the units were initially developed for monolingual middle to upper elementary grades. To accommodate for younger elementary students, the developers offer modification to worksheets used for key activities. However, additional modification, particularly for kindergarten students, was required to enable younger ELs to benefit from the learning activities. For example, the suggested modifications for younger age groups centered on utilizing simplified worksheets during activities. Our sample included kindergarten and first grade students who were not yet literate in either English or Spanish and, thus, required additional developmental modifications to the worksheets such as visual cueing and the organization of activities to include more teacher modeling of tasks and integrating the gradual release of the instructional framework (i.e., I do., We do., You do.).

2.4.2 | Linguistic scaffolds

Similarly, the developers offer some language scaffolds for ELs for the unit, but they focus on clarifying vocabulary, not disciplinary literacy as defined here. Disciplinary literacy in this study was supported by linguistic scaffolds in the form of sentence starters for use in pair and group discussions as well as targeted oral language practice in pairs. Disciplinary literacy activities were additionally supported with scaffolds that purposefully aid comprehension of key disciplinary practices including descriptions, explanations, and arguments. Two important scaffolds were the integration of oral language practice and academic conversations. The oral language practice routines integrated into the unit make explicit the interactional styles that are expected and necessary when engaging in the EDP as well as in connecting to the science involved in the engineering design task. The sequence of oral language practice gradually built up the expectation of disciplinary language practices (building on, challenge, and reason). Initially, oral language practice activities were designed to address behavioral aspects such as positioning for active listening and meaningful pair participation in disciplinary conversations. More direct practice in active listening was promoted with prompts and response frames designed to stimulate repetition and elaboration of disciplinary content (e.g., science and EDP vocabulary). These types of activities early in the unit build the background information necessary for appropriating SE discourse patterns needed for more challenging tasks later in the unit (building on, challenge, reason).

2.4.3 | Academic conversations

Teachers engaged students in academic conversations (Zwiers & Crawford, 2011) during the exploring materials and reviewing the science phases of the intervention to introduce students to specific interactional styles needed to make claims, build on evidence posed by group partners, or present counterarguments to design decisions. These instructional techniques build on past research in classroom discourse and cooperative learning (e.g., Aguirre-Muñoz & Gregory, 2019; Cazden, 2001; Tharp & Gallimore, 1991; Mercer, 1995; Vygotsky, 1978; Rogoff, 1990). Instructional conversations that focus on academic content, in particular, have been linked to increased achievement (Tharp & Gallimore, 1991; Goldenberg, 1991), prolonged engagement in SE tasks (Aguirre-Muñoz & Pantoya, 2016), and appropriation of disciplinary discourse in SE instruction (Aguirre-Muñoz et al., 2018). Academic conversations are also ideal for young ELs because their first and second language literacy skills are still emerging (Aguirre-Muñoz & Pantoya, 2016). The goal of the academic conversations later in the unit was to improve productive conversations among students aligned with disciplinary language use. Figure 2 presents a second grade academic conversation excerpt from Aguirre-Muñoz et al.'s (2018) study that demonstrated three language functions: building on, challenge, and reasoning.

Given the three aims of the study stated above, we address three research questions listed below. Heretofore, we refer to the modified unit as Engineering Everything (E^2).

Leila:	…it going to be limestone or alabas
Myrna:	/alabaster. I agree but we need to choose one. [Glances at teacher] We need to think like engineer do.
Teacher:	I like that Marco has his engineer hat on to make this decision. It's an important decision for the museum.
Florencia:	Let's look at our data paper sheet thing. …The Limestone, …we were able to carve on it and the line was very clear. The *alabastro* {alabaster}
Leila:	/we carved it but [pulls out the alabaster sample they carved on] the line is harder to see. //So// it's harder but harder to carve on.
Florencia:	Yeah, **does that mean it's [points to alabaster] more durable**? **That is better, no**?
Leila:	I agree (the alabaster is more durable and hard.) …But we still gotta carve on it, //so// is it the best choice?
Myrna:	Good question. Why is it harder to carve on it, something like structure. Look at the chart from yesterday, …durability is
Florencia:	/its important for carving but not museum. Right there on the [concept] map chart. My vote is for limestone.
Leila:	I agree //because// the durability is important for the museum, but only if you can carve it. So I agree with Florencia.
Myrna:	Me too.

Symbol codes

/ signals overlapping utterances
… signal a brief pause
/ / word is added for clarity
italics signals Spanish utterances
text in [] brackets signals student or teacher actions
text in {} brackets signals translations of Spanish utterances
Text in ( ) signals paraphrasing
Text in // // includes a logical connector signaling reasoning
Bold text signals building on
Double underline signals a challenge
Dashed underline signals reasoning

FIGURE 2 Excerpt from second grade academic conversation during science and engineering instruction illustrating three disciplinary discourse patterns: Building on, challenge, and reason

The specific research questions investigated were the following:

1. What is the impact of the E^2 activities on learning of (a) science and engineering and (b) technology for students in kindergarten to second grade?
2. What is the impact of the E^2 activities on engineering identity for students in kindergarten to second grade?
3. What is the relationship among engineering identity, science and engineering knowledge, and technology knowledge? Does the relationship vary by gender or grade level?

3 | METHODOLOGY

3.1 | Participants

3.1.1 | Teachers

Eighteen teachers from a large charter school in a large urban city in the Southwest participated in the study. Half of the classrooms were randomly assigned to the E^2 intervention and half to the control group. Teachers were matched based on educational background (highest degree obtained) and years of teaching experience. Fourteen teachers were female and four were male. The great majority of teachers were Latinx (78%), and the remaining teachers were African-

American (21%). Educational background and teaching experience were comparable among E^2 and control groups with 78% in both groups holding a bachelor's degree and 22% holding a master's or more advanced degree. In terms of years of teaching experience, two teachers (22%) in each group had 3–5 years of teaching experience; four teachers (44%) of each group had 6–10 years of teaching experience; and three teachers (33%) of each group had 16 or more years of teaching experience. Five teachers (56%) from each group were certified to teach in bilingual or English as a second language in elementary classrooms.

3.1.2 | Students

Eighteen urban classrooms totaling 368 students in kindergarten (125), first (110), and second grade (133) participated in this study. As illustrated in Figure 3, demographic characteristics between E^2 and control group students were comparable across all three grade levels. Across the three grade levels, the majority of E^2 and control students spoke Spanish in their home (Table A1). The sample for kindergarten and first grade was also overwhelmingly classified as Beginners in English development (99% and 83%, respectively, for kindergarten and first grade). Most (60%) second grade students were classified as Intermediate as one would expect given teaching and time in the United States. The proportion between E^2 and control group students was also comparable.

Figure 3 also presents the percentage of achievement and reading ability levels for each grade. Although these background characteristics varied slightly between E^2 and control groups within grade levels, differences between groups were not statistically significant for the first and second grade samples, $F(1, 106) = 1.58$, $p = .43$ and $F(1, 129) = 72.17$, $p = .08$, respectively, for reading ability; $F(1, 106) = 2.20$, $p = .38$ and $F(1, 129) = 5.73$, $p = .25$ for first and second grade levels, respectively, for achievement. Gender differences or gender by treatment group interaction for these variables were also not statistically significant (p's > .05). However, the kindergarten gender by treatment group

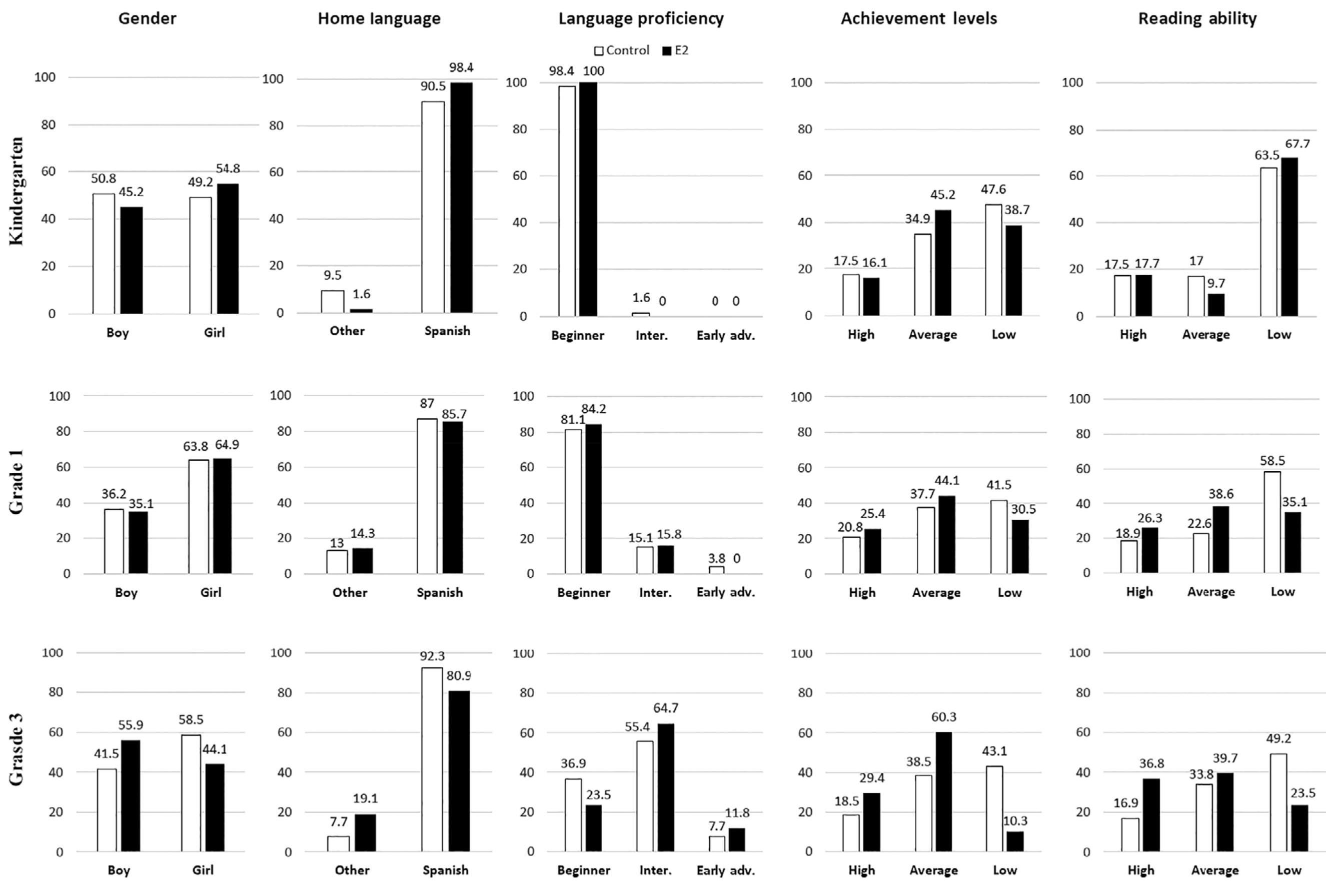

FIGURE 3 E^2 and control group demographic characteristics for each grade level. E2 = E^2: Engineering Everything; Early adv. = early advanced; Inter. = intermediate; Y axis scale unit is percentage

interaction effect of achievement between treatment and control groups was statistically significant, $F(1, 121) = 4.58$, $p = .034$. Consequently, this variable was statistically controlled in the kindergarten analyses only.

3.2 | Study design and analysis

To answer the first two research questions, a 2 (instruction group: intervention or control) by 2 (gender: male or female) factorial design was implemented. Tables A1–A4 in the Appendix present the sample sizes for each grade level by treatment and gender. Separate repeated measures analysis of variance (ANOVA) were conducted for each grade level to compare the effects of instruction group (intervention or control) and gender (male or female) on three dependent variables: (1) SE content knowledge, (2) technology knowledge, and (3) engineering identity. As noted above, in the kindergarten analyses, achievement was used as a covariate in the analysis to control for initial group difference. To answer the third research question, correlations were computed to examine the relationships among the variables examined.

3.3 | Description of the intervention

As discussed previously, we modified an EiE unit, *Sounds Like Fun: Seeing Animals Sounds* (Boston Museum of Science, 2015), to integrate (1) developmental scaffolds corresponding to the younger sample and (2) linguistic scaffolds targeting disciplinary literacy as well as (3) cultural accommodations to promote interest and active cognitive engagement in the activities. Table 2 displays the instructional goals for the *Sounds Like Fun* unit. In the EiE model, units integrate narrative texts, contextualized science learning and problem-solving, collaborative learning, communication, and problem-based learning. The premise of the EiE curricular model is to increase elementary school students' technological literacy defined as developing essential knowledge in the following areas: (1) an understanding of engineering, technology, and the work of engineers; (2) sound engineering; (3) multiple solution paths to engineering problems; and (4) diversity of engineers' backgrounds (races, ethnicities, and genders). This knowledge includes the following key skills: (1) application of EDP; (2) application of science and math in engineering; (3) learning from failed designs; and (4) understanding the central role of materials and their properties in engineering solutions.

The E^2 unit maintained the EiE curricular model but modified curricular activities and materials to maximize ELs' productive engagement and learning. Since the E^2 intervention was integrated into the larger science unit (properties of matter), all teachers (E^2 and control) introduced fundamental science concepts (e.g., matter, sound, vibration) related to the unit the week prior to the start of the E^2 unit as part of the regular science curriculum. Corresponding materials (sound and vibration concepts) were presented using teachers' normal instructional practices prior to the start of E^2.

TABLE 2 Instructional goals for modified Engineering is Elementary (EiE) units related to targeted knowledge and skills

	Solid as a rock: Earth science in materials engineering context
Knowledge	a. Identify and define technology b. Define an engineer and an acoustical engineer c. Identify vibrations as the source of all sound* d. Recognize sound properties including volume and pitch* e. Recognize properties of vibrating objects (size and tension) affect pitch* f. Identify techniques for stopping or absorbing vibrations* g. Identify primary and competing sounds from experience h. Identify steps of the engineering design process i. Identify and compare the performance of different techniques for damping sounds: stopping and absorbing
Skills	a. Explain the work of acoustical engineers in developing new and improved materials b. Sort, describe, and analyze materials according to a variety of properties c. Perform experiments to test materials and methods to damp sound vibrations: size and tension d. Imagine, plan, and create a representation system for drum beat sounds* e. Test sound representations* f. Communicate patterns from experimentation* g. Apply results of experimentation to make decisions about engineering designs (tactile representation)

Note: Goals with asterisk (*) signal science content.

During the E^2 instruction period, E^2 intervention students were reintroduced to these concepts in the context of the SE unit, whereas the control students were reintroduced to them during a structured inquiry activity that was part of the regular curriculum. Thus, in addition to the language and development scaffolds that reflect the E^2 approach, modifications to daily lessons integrated review and elaboration of key science concepts in the engineering context, most directly in the exploring materials and engineering challenge phases of the E^2 unit.

The intervention units were delivered over six to seven days in the Fall Semester; kindergarten lessons spanned over seven days to accommodate their shorter attention spans and provide the additional modeling needed to complete the challenge. Instructional activities, scaffolds, and accommodations for each day of the intervention are summarized in Table 3. Day 1 activities focused on understanding technology and the role of technology in the work of engineers with the use of a picture book (*Engineering Elephants*) and hands-on activities. Days 2 and 3 presented a narrative text teachers read aloud to introduce an authentic multicultural context involving a problem that is solved utilizing the EDP. The story featured the use of a tactile spectrogram (i.e., engineering solution) to represent a drum rhythm Kwame (protagonist) created for his cousin to use for practice prior to performing at a cultural festival. In addition to questioning before, during, and after the reading aloud of this story, vocabulary was reinforced using the total physical response (TPR; Asher, 1969) strategies and cue cards to scaffold the SE content. TPR is a method of teaching language or vocabulary concepts using physical movement to react and thereby create a cognitive link between speech and action to boost language and vocabulary learning (Asher, 1969). Day 4 activities presented a broader view of sound engineering. Students examined the properties of sound and their sources (vibration); they tested methods for damping sounds to compare and contrast their effect on vibration. Day 5 activities targeted the use of scientific practices to identify the properties of sound, represent those properties (spectrogram), and explicitly link SE for students. Day 6 (and 7 for kindergarten) activities presented an engineering challenge that required students to apply relevant scientific knowledge and skills and the EDP to create and test a sound representation system.

3.3.1 | Unit modifications

The guiding principle of the modifications was to integrate an explicit focus on developing young ELs' use of disciplinary language to make sense of engineering tasks, science content, and the EDP. These modifications included developmental and linguistic scaffolds, cultural accommodations, and frequent opportunities for explicitly practicing disciplinary literacy skills in academic conversations (Table 3). Developmental scaffolds centered on providing ELs with background information using concrete, tactile, and visual supports. In addition, cognitive load was reduced in the worksheet exercises by decreasing the level of inference involved as well as in increasing visual cues to promote developmentally appropriate inferencing of inquiry tasks. Linguistic scaffolds featured common language learning scaffolds such as the use of the gradual release model, tactile and kinematic activities (i.e., TPR) to amplify language learning, and sentence starters to explicitly prompt disciplinary literacy. Academic conversations provided the structure for frequent disciplinary literacy practice by supporting student elaboration and organization of the SE content. Teachers engaged students in academic conversations on each day of the treatment with the use of sentence starters to support the linguistic productivity and use of content vocabulary. In addition, because culturally relevant instructional materials have been found to contribute to minority students' positive attitudes, interest, and identity development (Barton & Tan, 2010; T. D. Lee et al., 2019), a cultural accommodation was integrated into the engineering design task. Instead of using birdcalls to design a sound representation, drumbeat sounds were created by utilizing an internet-based sound generator. This tool allowed us to manipulate changes in sound pitch, volume, and duration to make changes more explicit for young ELs. Students were able to connect to drumbeats because they are a prominent instrument in Latinx traditional music. In addition, students were provided with drums on Days 2 and 3 to explore properties of sound vibrations, and students made connections to the music they listen to at home. A drum is also featured in the storybook, *Kwame's Sound*, allowing for additional cognitive and cultural connections they would draw upon for completing the challenge on the final day of E^2 instruction.

3.4 | Teacher training

E^2 intervention teachers participated in a one-day training session that targeted the implementation of the intervention. Teachers were trained on the concept of technology and its relationship to engineering. In the process of familiarizing teachers with the unit materials, they were trained on interactive read-alouds with the use of TPR and other active engagement techniques (cue cards) to enhance story recall and recall of key SE vocabulary. Teachers practiced reading

TABLE 3 Sounds Like Fun unit engineering-centered daily activities, developmental and linguistic scaffolds, cultural accommodations, and academic conversations foci

	Activity	Developmental scaffolds	Linguistic scaffolds and cultural accommodations	Academic conversation foci
Day 1	(1) *Technology in a bag*: Explored everyday technologies that are not electric and are related to the engineering story (Day 2) and challenge (Day 6)	Students generated a definition and refined it after hands-on exploration of technologies	*Linguistic*: Think–Pair–Share to practice technology vocabulary *Cultural*: Musical instruments from ELs' home countries were integrated into activity	AC were introduced, practiced, and used to daft technology definition
	(2) *Read aloud and design sketch*: Teachers read the picture book *Engineering Elephants*	Engaged students in sketching activity to activate thinking about technology and promote engineering identity	*Linguistic*: Used SS to support young learners and early English proficient students	AC used to refine technology definition based on reading focusing on rephrasing others' contributions
Day 2–3	*Read aloud*: Teachers read EiE storybook, *Kwame's Sound*	*Concrete objects*: Before reading, explored how musical instruments make sounds with concrete musical instruments including drums *Visual cues*: Watched slow motion videos of different types of vibrations of everyday objects and of guitar strings *Tactile cue*: Placed their hands on their throat to feel the vibration of their voice	*Textual*: Shortened story (50%) to reduce linguistic load, but maintained key events reflecting science content and EDP cycle *Tactile*: Reviewed key story vocabulary with concrete objects and kinematic games (Simon says); Used CC and TPR emphasize EDP and key vocabulary *Cultural*: Toy musical instruments from ELs' home countries were used	Before reading, students modeled good academic conversation behaviors; after reading, AC used to summarize EDP in story focusing on building on others' contribution
Day 4	*Hands-on inquiry activities*: Students construct a guitar to learn (1) how sound is made; (2) how sound is damped; and (3) what sound engineers specialize in and do	*Task cognitive load*: Observation recording sheets modified for age group	*Cultural*: Musical instruments from ELs' home countries were featured in pictures *Linguistic*: Used SS to prompt student agreement and disagreement with observations	Used AC to summarize science concept learning from tuning fork activity and focused on building on others' contributions
Day 5	*Hands-on inquiry activities*: Using recordings of bird sounds, students learn: (1) to represent pitch, volume, and duration (tactile/concrete spectrogram) and (2) to create representations (spectrograms) of bird sounds representing two properties simultaneously	Teachers' reread the part of the story that demonstrated how Kwame represented his sound (tactile/concrete spectrogram with dried noodles) *Task cognitive load*: Kindergarten students learned how to represent only two sound properties (volume and duration) not three (pitch) and created representations of the two they learned about; Kindergarten represented the two properties separately	*Procedural scaffold*: Teacher used gradual release approach to model spectrograms *Linguistic*: Used SS to prompt student agreement and disagreement with observations	Used AC to imagine and plan representations of sound and focused on challenging others' contributions
Day 6 (& 7 for kinder)	*Engineering design task*: Students use their understanding of sound properties and the design process to design and improve a sound representation	Design sheets modified for this age group. Teachers' reread the part of the story that demonstrated how Kwame engaged in the EDP Sounds were longer to make it easier to detect differences over time	*Procedural scaffold*: Kindergarten teacher co-created first design with visuals; students tested her design. Students created tactile version of the teacher's design *Cultural*: Used drum beats instead of bird calls	Used AC to review unit concepts and reason about sound representations

Abbreviations: AC, academic conversation; CC, cue cards; CM, concept map; EDP, engineering design process; ELs, English learners; SS, sentence starters; TPR, total physical response.

the story, *Kwame's Sound*, using the TPR strategy and were given feedback on their attempts. This was repeated until they achieved adequate performance on the strategy. Finally, the training targeted the implementation of the academic conversation activities. This included videos of teachers implementing the strategy followed by modeling from the research team. Teachers then engaged in role-playing with feedback from other teachers and the research teams. After the research team demonstrated the lessons teachers were to enact with their students, they were given an opportunity to modify the lesson plans provided to meet their specific scheduling and classroom needs.

3.4.1 | Teaching fidelity

E^2 teachers were observed by a member of the research team three times during the intervention period to ensure fidelity of the instructional approach. A previously tested (Aguirre-Muñoz & Pantoya, 2016; M. L. Pantoya & Aguirre-Muñoz, 2017) observation protocol (Appendix Table A5) was used to record fidelity to the disciplinary literacy components of the lessons developed. The observations focused on three components of disciplinary literacy: (1) the book reading activities including the *Engineering Elephants* read-aloud, (2) the academic conversations that occurred on each day of observation, and (3) the EDP on the sixth (and seventh for kindergarten) day of the intervention. The book reading component comprised of seven instructional moves that captured both read-aloud best practices and the scaffolding strategies they were trained on for the book reading. The academic conversations component comprised instructional moves that reflected best practices and scaffolding integration. The EDP component comprised three instructional moves that targeted review and scaffolding of steps in the EDP process. Each of the instructional moves were coded on a five-point scale ranging from “0” representing “not observed” to “4” representing observed “very often.” Two raters observed a random sample of five E^2 teachers and rated them on the fidelity rubric at the conclusion of the lesson. Kappa coefficients for these three components were 0.83, 0.86, and 0.86, respectively, indicating solid reliability for the coding system. Results confirmed that all of the E^2 teachers followed the intervention as designed.

3.5 | Measures

3.5.1 | Science and engineering learning assessment

To collect evidence of SE learning, one of two versions of the Science and Engineering Learning Assessment (SELA; M. L. Pantoya & Aguirre-Muñoz, 2017) was administered to students prior to the start of the unit and a second version was administered at the unit's conclusion. SELA is an adaptation of the previously validated Science Learning Assessment (SLA; Samarapungavan et al., 2009) that measures science learning for kindergarten to second grade students. The SELA consists of 15 items comprising three dimensions: (1) five items assess children's understanding of inquiry processes; (2) five items assess their understanding of science concepts targeted by the inquiry lesson; and (3) five items assess their understanding of EDP. SELA items follow a format in which the student is shown three pictures and asked a question about these pictures that could be answered verbally or by pointing to or circling their selected pictures. A binary coding scheme (correct or incorrect) was used to score SELA items. The total number of points possible is 15. Reliability (Cronbach alpha) for the total score of this measure was 0.71, 0.76, and 0.83 for kindergarten, first grade, and second grade samples, respectively. These coefficients reflect acceptable to good reliability for the total score. Reliability for some of the dimensions was less than 0.60 and thus the total score was used in the analyses.

3.5.2 | Technology knowledge assessment

The previously validated Technology Knowledge Assessment included in the EiE unit (Cunningham et al., 2005) was administered to students to determine the impact of the intervention on basic technology knowledge. Technology knowledge is operationalized as the identification of everyday technologies (e.g., basket, sandals, etc.) and the ability to distinguish technologies from objects in the natural world (e.g., bird, tree, etc.). Students are presented with pictures of 20 items that comprised a set of technologies (16 items) and a set of objects from the natural world (4 items). Students were instructed to circle the items that represent technology items. Points are given for correct identification of items as examples or non-examples. Thus, totaling 20 points for this assessment. Cronbach alpha coefficients on the total score were 0.87, 0.76, and 0.88 for kindergarten, first grade, and second grade, respectively. Thus, reliability was within the acceptable to good range.

3.5.3 | Engineering identity development scale

The engineering identity development survey (EIDS) scale was developed and validated by Capobianco et al. (2012, 2015) and is comprised of 20 items that measure two dimensions of engineering identity development (academic identity and engineering career). Examples of the general academic items include "I do my school work as well as my classmates" and "I am good at solving problems in mathematics." Examples of the engineering career items include "When I grow up I want to be an engineer" and "Engineers design everything around us." Students were asked whether they agreed or disagreed with each item. Level of agreement was represented by a smile emoji reflecting "agree," "not sure," "disagree." In effect, responses are a three-point Likert scale with "1" representing "disagree," "2" representing "not sure," and "3" representing "agree." Capobianco et al. (2012) report reliability for the total score as 0.76. Like Capobianco et al. (2012), the reliability coefficient for academic identity fell below 0.60; therefore, total score was used in the analyses. Cronbach alpha coefficients on the total score for our samples were 0.86, 0.82, and 0.78 for kindergarten, first grade, and second grade, respectively. Like the two other measures, these coefficients fall within the acceptable to good reliability range.

4 | RESULTS

Descriptive statistics for each outcome variable (SE knowledge, technology knowledge, and engineering identity) are presented in the Appendix (Tables A1–A4). Separate repeated measures ANOVAs were completed for each grade level to answer the first two research questions. For each analysis, time (pretest or posttest score) was the within-group factor, and instruction group (E^2 or control) and gender (male or female) were between-group factors. Initial analyses revealed that the kindergarten E^2 instruction group had significantly higher achievement ratings than their control group counterparts. These initial differences were not found for ELs in the first and second grade levels. Therefore, initial group differences were statistically controlled in the kindergarten analyses only.

4.1 | E^2 impact on SE and technology knowledge (Question 1)

4.1.1 | SE knowledge impact

The instruction group main effects for each grade level were statistically significant at the 0.05 level (Figure 4 graphs and Tables A6–A8). Instruction group mean comparisons (Figure 4, KA) indicate the kindergarten E^2 group's SELA performance growth was significantly higher than the control group ($p < .001$, partial $n^2 = 0.17$). The gender main effect and gender by group interaction were not statistically significant, (p's > .05). Like the kindergarten results, E^2 instruction had a significant effect on first grade SELA posttest scores ($p < .001$, partial $n^2 = 0.31$). First grade SELA pretest to posttest means (Figure 4, FA) indicate the mean growth of the E^2 group, regardless of gender, was significantly higher than the control group at posttest. For this grade level, there was also a significant gender main effect, ($p = .043$). Regardless of the instructional group, girls' mean growth was significantly higher than boys' mean growth, but the magnitude of the effect was relatively small (partial $n^2 = 0.042$). There was a 0.70 mean difference in growth between girls and boys: a difference that is not practically significant particularly in light of the small effect size. The first grade gender by instructional group interaction effect was not statistically significant, ($p > .05$). Second grade SELA results mirrored the kindergarten results. A significant instruction group main effect ($p < .001$, partial $n^2 = 0.31$) indicated second grade students in the E^2 group had higher mean growth than the control group (Figure 4, SA). The gender main effect and gender by group interaction effect were not statistically significant (p's > .05).

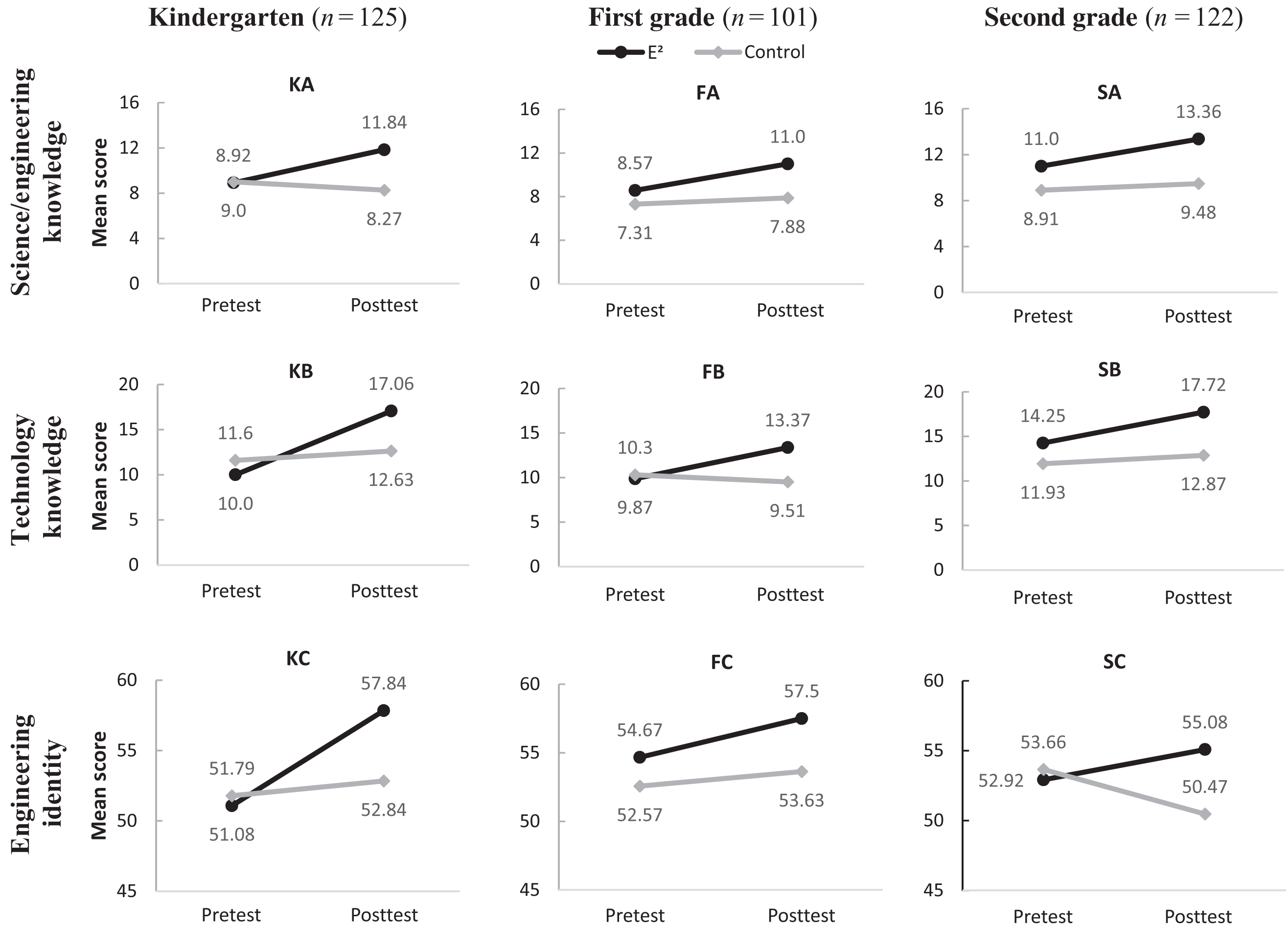

FIGURE 4 Engineering Everything (E^2) and control group mean score comparisons for each variable by grade level. All E^2 and comparison group posttest differences are significant, *p*'s < .05; FA–C, first grade graphs A–C; KA–C, kindergarten graphs A–C; SA–C, second grade graphs A–C

4.1.2 | Technology knowledge impact

The kindergarten E^2 group main effect was significant ($p < .001$), indicating a significant difference in technology performance growth between the kindergarten E^2 and control groups (partial $n^2 = 0.06$) favoring the E^2 group (Figure 4, KB). The gender main effect and gender by group interaction effect were not statistically significant (*p*'s > .05). First and second grade results mirrored the kindergarten results. The instruction group main effect was statistically significant (*p*'s < .05 and partial $n^2 = 0.09$, for first grade; partial $n^2 = 0.20$ for second grade). First and second grade students who received E^2 showed greater growth than the control group students (Figure 4, FB and SB, respectively). The gender main effects and gender by instruction group interaction effects were not statistically significant for any grade level (*p*'s > .05).

4.2 | Impact on engineering identity (Question 2)

The same pattern of results was observed for engineering identity as for the learning outcome variables presented above. The instruction group main effect for kindergarten was statistically significant ($p < .05$, partial $n^2 = 0.07$). Mean score comparisons (Figure 4, KC) indicate the growth in engineering identity was significantly higher for the E^2 group than the control group counterparts. Neither the gender main effect nor the gender by group interaction effect was statistically significant (*p*'s > .05). The same pattern of results was obtained for first and second grade ELs (see Figure 4, FC and SC). The EIDS mean growth for first and second grade students receiving the E^2 intervention was significantly higher than control group means (p's < .05; partial $n^2 = 0.10$ for first grade, and partial $n^2 = 0.05$ for second grade, respectively). The first and second grade gender main effect and gender by group interaction effect were not statistically significant (p's > .05).

4.3 | Relationship between engineering identity, SE knowledge, and technology knowledge (Question 3)

Figure 5 first presents the correlation analyses among the three outcome variables presented for all three grade levels combined, then disaggregated by grade level, and then by gender. When kindergarten through second grade ELs' scores are combined to examine early primary student trends, moderate and significant correlations were observed between each of the three variables. That is, significant and positive correlations were observed between SELA scores and technology knowledge ($r = 0.397$, $p < .001$), between SELA scores and engineering identity ($r = 0.256$, $p < .001$), and between technology knowledge and engineering identity ($r = 0.124$, $p < .001$). A similar pattern of correlations was observed for K-2 grade boys. Moderate and positive correlations were found between SELA scores and technology knowledge ($r = 0.407$, $p < .001$); between SELA scores and engineering identity ($r = 0.288$, $p < .001$); and a small positive but significant correlation between technology knowledge and engineering identity ($r = 0.161$, $p = .046$). For K-2 grade girls, moderate and positive correlations were observed between SELA scores and technology knowledge ($r = 0.393$, $p < .001$) and between SELA scores and engineering identity ($r = 0.235$, $p = .001$). Kindergarten to second grade girls' technology knowledge was not associated with engineering identity.

When the data were disaggregated by grade and gender, variations in the pattern of associations were observed. For kindergarten, small but significant correlations were found between SELA and engineering identity ($r = 375$, $p = < .001$) and between technology knowledge and engineering identity ($r = 0.263$, $p = < .003$). Examining disaggregated kindergarten data by gender, we found a positive correlation for the boys' scores between SELA and engineering identity ($r = 0.346$, $p = .007$). Kindergarten boys' engineering identity was not associated with technology knowledge. For kindergarten girls, engineering identity was significantly correlated with SELA scores ($r = 0.478$, $p < .001$) and technology knowledge scores ($r = 0.439$, $p < .001$).

	K-2 boys & girls			K-2 boys			K-2 girls		
	1	2	3	1	2	3	1	2	3
1. SELA	–	0.397* (344)	0.256* (349)	–	0.407* (152)	0.288* (155)	–	0.393* (192)	0.235* (194)
2. TECH		–	0.124† (348)		–	0.161† (154)		–	0.096 (194)
3. EIDS			–			–			–
	Kinder boys & girls			**Kinder boys**			**Kinder girls**		
1. SELA	–	0.154 (125)	0.375* (125)	–	0.163 (60)	0.346* (60)	–	0.161 (65)	0.478* (65)
2. TECH		–	0.263* (125)		–	0.074 (60)		–	0.439* (65)
3. EIDS			–			–			–
	Grade 1 boys & girls			**Grade 1 boys**			**Grade 1 girls**		
1. SELA	–	0.505* (104)	0.360* (105)	–	0.342† (39)	0.591* (39)	–	0.618* (65)	0.239^{+} (66)
2. TECH		–	0.291* (105)		–	0.365† (40)		–	0.252^{+} (65)
3. EIDS			–			–			–
	Grade 2 boys & girls			**Grade 2 boys**			**Grade 2 girls**		
1. SELA	–	0.512* (115)	0.298* (119)	–	0.675* (53)	0.391* (56)	–	0.401* (62)	0.229 (63)
2. TECH		–	0.130 (118)		–	0.233 (54)		–	0.053 (64)
3. EIDS			–			–			–

FIGURE 5 Relationship among engineering identity development survey (EIDS), science and engineering learning assessment (SELA), and technology knowledge assessment (TECH). Numbers in parentheses are the sample sizes; * correlation significant at the 0.01 (two-tailed) level; † correlation significant at the 0.05 (two-tailed) level; $^{+}$ correlation approaching significance

Examining the relationship among all first grade students, a positive and moderate correlation was found between technology and SELA scores ($r = 0.505$, $p < .001$). In addition, small but significant correlations were found between engineering identity and SELA scores ($r = 0.360$, $p = < .001$) and between engineering identity and technology scores ($r = 0.291$, $p = .003$). Significant and moderate to high correlations were found for first grade data disaggregated by gender. Among the first grade boys, positive and significant correlations were found between the SELA and technology scores ($r = 0.342$, $p < .05$). The SELA and technology scores were also positively associated with engineering identity scores ($r = 591$ and $r = 0.365$ respectively, p's $< .05$). For first grade girls, a high and positive correlation was found between SELA scores and technology knowledge scores ($r = 0.618$, $p < .01$). The correlations between girls' engineering identity and SELA were nearly significant ($r = 0.239$, $p = .053$) as was the correlation between engineering identity and technology knowledge ($r = 0.252$, $p = .053$).

For all second grade students, a moderate to high and positive relationship was found between technology and SELA scores ($r = 0.512$, $p < .001$). In addition, a small positive but significant correlation was found between engineering identity and SELA scores ($r = 0.298$, $p = .001$). Second grade engineering identity was not significantly associated with technology knowledge ($r = 0.130$, $p = .161$). Disaggregated second grade data by gender reveal positive and high associations between boys' SELA scores with technology knowledge ($r = 0.675$, $p < .001$) and engineering identity ($r = 0.391$, $p = .003$). Second grade boys' engineering identity was not significantly correlated with their technology scores ($r = 0.233$, $p = .089$). For second grade girls, the only significant correlation was found between SELA scores and technology scores ($r = 0.401$, $p = .001$). Second grade girls' engineering identity was not associated with either their SELA scores ($r = 0.229$, $p = .071$) or their technology knowledge ($r = 0.053$, $p = .680$).

5 | LIMITATIONS

There are some limitations to the design of the study that should be considered when interpreting the results. The first limitation is the underexplored validation of the SELA measure. Recall that the SELA utilized in this study is a modified version of the SLA (Samarapungavan et al., 2009). Given the nature of the modification, the psychometric properties of the original scale may not translate to the adapted version. The reliability evidence collected was comparable to the original measure, but additional validity evidence is needed to strengthen the inferences that are drawn from the scores. Therefore, future research can focus on examining the psychometric properties of the SELA.

Second, given that our sample only included ELs from kindergarten to second grade, it is not possible to generalize the findings of the study to non-ELs nor ELs from other grade levels. A report by the National Academies of Sciences, Engineering, and Medicine (2018) found that ELs are usually denied full access to STEM education while their non-ELs peers have better access to this type of education in and out of school. Therefore, non-ELs may react differently to the E^2 intervention. Given that non-ELs, by definition, are proficient in English, the language scaffolds may not be appropriate for them. Given the role of language in content learning for all students (see Kieffer et al., 2009; Resnick et al., 2015), it is likely that the language scaffolds will be helpful for non-ELs; however, the magnitude of the effect would likely be lower than the magnitude of the effect observed with ELs in this study.

The third limitation is similar to the first. Although this study indicates promising results for engineering identity development, the EIDS measurement instrument was created for students in first to fifth grades. Given we studied kindergarten and EL students, further research is needed to investigate more fully EIDS accuracy for kindergarteners and ELs. The moderate and significant association with the other content measures provides some evidence of its construct validity (Newton & Shaw, 2014).

6 | DISCUSSION

6.1 | SE knowledge gains

The study reported here builds on the study by Aguirre-Muñoz and Pantoya (2016) by demonstrating that early primary ELs can benefit from integrated SE instruction. As more engineering education curricula are being developed and delivered in early primary grades, it is vital that evidence-based scaffolding approaches are utilized to ensure equitable learning outcomes for ELs. Our findings are consistent with past research studies that show positive gains in content, technology, and identity development when experimental groups are exposed to SE interventions. Further, our study indicates these gains are also possible in younger age groups in comparison to similar research studies focused on intermediate and higher elementary grade levels (e.g., Yoon et al., 2014).

To further compare these results with past studies, we converted the partial eta square indices to Cohen's d (e.g., Wendell & Rogers, 2013; Yoon et al., 2014), finding the magnitude of the curricular impacts was larger (1.48, 1.58, and 1.52, respectively, for kindergarten, first grade, and second grade) than other studies (ranging from 0.23 to 1.14). Further, the magnitude of the effect did not vary substantively by grade level. Thus, despite the shorter duration of the E^2 intervention, the E^2 curricular design strategy yielded strong impacts for this vulnerable group across the three grade levels. The observed effect sizes of the impact on the technology assessment were smaller than for SE knowledge. The difference on impact can be attributable to less time spent on making direct links to technology during the E^2 intervention. SE content was explicitly targeted throughout the E^2 intervention, whereas technology content was only explicitly targeted on the first day of the intervention. Malone et al. (2018) utilized the same measure and reported Cohen's d on this measure as 0.94, 0.85, 0.52, and 1.78 for kindergarten, first, second, and third grade levels, respectively. Calculating Cohen's d for the effects of this study revealed that the magnitude of the impact for all three grade levels was 1.15, 1.12, and 1.22, for kindergarten, first, and second grade, respectively. Like the SE knowledge results, the E^2 curricular design strategy yielded strong technology knowledge impacts for ELs across grade levels.

Despite these positive outcomes, inequitable learning outcomes can result when the learning needs of different groups of students are not considered in the design of integrated SE instruction. Guzey, Morse, and Moore (2016) found that Latinx and African-American students performed significantly lower on achievement measures. The contribution of this study highlights the importance of utilizing a scaffolding approach emphasizing disciplinary language tools and culturally relevant engineering tasks in reaching more equitable outcomes for this vulnerable student group. Future studies could examine the unique contributions of specific scaffolding strategies to determine their effectiveness in increasing content understanding. For example, the unique contributions of the frequent academic conversations would shed light on the role of oral language practice on ELs' understanding and use of disciplinary literacy in SE contexts as well as ELs' contributions in the EDP.

6.2 | Gender impacts on knowledge gains

The gender main effects in favor of first grade girls' content knowledge could have been attributable to the proportion of girls in classrooms. The proportion of girls in the first grade sample (63.1%) was larger than in the kindergarten (52.0%) and second grade samples (51.1%). It is possible the increased number of girls in this grade level affected the nature of the interaction dynamics during E^2 activity. Having a larger sample could have increased girls' opportunities to see other girls succeed in engineering tasks. Stout et al. (2011), for example, found girls' increases in performance were linked to seeing oneself as part of the in-group. The higher proportion of girls in first grade classrooms may have resulted in more girls taking active roles in the EDP. This experience may have bolstered girls' confidence in STEM content, which resulted in their higher performance.

6.3 | Impacts on engineering identity

Although the impact of E^2 on engineering identity was positive overall, the magnitude of the effect was low for each of the three grade levels. Given that past research is mixed, with several studies showing no impact on attitudes and identity development for students receiving integrated SE instruction (e.g., Lie et al., 2019; Wendell & Rogers, 2013), the positive effect is noteworthy. Further, the effect sizes observed were within the range of those reported by year-long interventions such as Capobianco et al.'s (2017, partial n^2 from 0.027 to 0.144) and Yoon et al.'s (2014, partial n^2 from 0.038 to 0.178). Given the short duration of E^2, the magnitudes of the observed effects are interpreted as meaningful.

However, girls' confidence may have not been consistent across grade levels as the correlational analyses indicated once disaggregated. The inconsistent relationship among the variables observed for second grade could be attributable to the short intervention period as well as the SE contexts presented for the unit. Recall, the story featured a boy (Kwame) and his father engaging in the EDP process. Although Kwame enlisted the help of his sister, he took the lead in all aspects of the EDP. The lack of a female role model in the story may have reinforced the misconception that engineering is primarily a masculine field. This notion is consistent with past work demonstrating that even when female test performance in STEM improves, their identity may not follow (e.g., McGregor et al., 2008). Stout et al. (2011)

demonstrated that inculcation by same sex role models can improve test performance and self-concepts in a stereotyped domain such as engineering.

Although not measured in this study, other studies have found lower levels of confidence and self-efficacy in female students (e.g., Besterfield-Sacre et al., 2001; Eddy & Brownell, 2016). It is, therefore, also possible that the disparity in confidence and self-efficacy begins in early elementary school, and this contributes to the inconsistent association between identity and content outcomes. Future research including self-efficacy measures would shed light on this issue. It may also indicate differences in opportunity reinforced by under-trained teachers. In a recent study examining predictors of SE content learning and identity development, Lie et al. (2019) found that teachers who had 2 years of professional development in integrated SE instruction predicted student attitudes toward engineering. Teachers in the study reported here received 8 hours of training. It is possible that teachers need additional training to support girls' positive attitudes toward engineering.

7 | CONCLUSION

7.1 | Content learning

The current study sought to test the impact of integrated SE instruction on primary ELs' SE knowledge, technology knowledge, and engineering identity development. ELs in the E^2 instruction group outperformed the control group students on the SELA posttest measure. The results indicate that integrated SE instruction, scaffolded with disciplinary language supports and cultural accommodations (E^2), significantly increased EL's SE knowledge as well as their technology knowledge. Although this study was not designed to examine the unique contributions of scaffolds and cultural accommodations integrated into the SE unit, the findings provide support for their use with young ELs who are at beginning and intermediate English levels of proficiency.

In addition, no significant gender main effects or gender by intervention interaction effects were found for SE learning in the kindergarten and second grade samples. These findings suggest that regardless of gender, SE instruction with linguistic scaffolds and cultural accommodations is promising for improving ELs' content learning in early elementary grades. In the first grade analysis, we found a significant gender main effect in favor of girls. This effect indicates that regardless of the instructional group, girls' SE knowledge growth, overall, was higher than boys' scores (discussed further in Section 6).

7.2 | Engineering identity development

The findings also revealed significant development in engineering identity at all three grade levels for ELs who received E^2 instruction. The analysis of the engineering identity assessment scores showed consistent and significant gains for students receiving the E^2 instruction, and they reported higher gains in identity development than their control group counterparts. Further, no gender differences were found for engineering identity growth at any of the grade levels, suggesting that integrated SE instruction affected boys' and girls' identity equally. Overall, girls receiving the E^2 instruction were just as positive toward engineering as the boys were.

7.3 | Relationship among variables

Increases in K-2 grade ELs' engineering identity development were associated with increases in SE knowledge as well as technology knowledge. These findings suggest that exposing ELs to carefully scaffolded SE instruction promotes a self-belief that they can become an engineer. When the data were disaggregated by grade level and gender, the pattern of associations varied. Increases in engineering identity continued to be associated with SE knowledge for all three grade levels. Disaggregated by grade level, engineering identity was significantly and positively associated with technology knowledge for kindergarten and first grade samples but not for the second grade sample. Additionally, technology knowledge was positively associated with SE knowledge for first and second grade students, but not for kindergarten students. Disaggregating the combined K-2 grade data by gender showed that increases in engineering identity were associated with increases in SE knowledge for both gender groups. However, K-2 grade girls' engineering identity was not associated with technology knowledge. When data were disaggregated by grade and gender, the relationship was significant and positive for kindergarten and first grade girls but not for second grade girls. Second grade girls' engineering identity was not associated with technology knowledge nor SE knowledge as was observed with the boys.

8 | IMPLICATIONS

8.1 | SE knowledge gains

This study underscores the need to engage early elementary school ELs in engineering practices to develop a broader understanding of the work of engineers, increase student content knowledge, and develop a self-concept that contributes to a positive engineering identity. Teachers and curriculum designers should purposefully and meaningfully connect science concepts with engineering design tasks and use carefully designed language scaffolds and cultural accommodations to support positive learning outcomes for ELs. This is particularly important in early science learning experiences because past research indicates that sustaining interest in science requires experiences that provide opportunities to engage with science content that connects to their experiences (Hidi & Renninger, 2006) and predicts later expressions of interest in science (Ainley & Ainley, 2015). Future studies should examine the extent to which these relationships also pertain to engineering experiences.

8.2 | Gender impacts

Structuring activity to balance participation in prominent roles during inquiry and design activity may address the second grade gender differences in identity development. Structuring the activity in this balanced manner creates a social environment that provides girls an opportunity to take on roles where they can see themselves as a person who "does engineering" (Ainley & Ainley, 2015, p. 21). These experiences cultivate identity development and confidence that lead to course taking patterns that place them on the pathway to SE careers (Ainley & Ainley, 2011). Future studies should include more direct measures of SE confidence and/or self-efficacy to examine this issue systematically. The lack of relationship between second grade girls' identity and performance could also reflect the need to further tailor the context of the SE activities that directly challenge stereotyped conceptions. Future studies should also examine the extent to which the gender of the protagonist in the story can influence girls' attitudes toward engineering. Finally, it is important to provide professional development opportunities to support teachers in instilling positive attitudes toward engineering. Training should also be directed at understanding differences in girls' interest in parts of the design phase. Rogers and Portsmore (2004), for example, found that elementary girls preferred discussion of the design phase, whereas boys preferred the building phase. Thus, teacher training should also focus on the developmental scaffolding sequence of the EDP that is sensitive to girls' preferences.

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APPENDIX

Descriptives, fidelity, and ANOVA results

TABLE A1 Background characteristics for E^2 and comparison group by grade level

	Kindergarten				First grade				Second grade			
	E^2		Control		E^2		Control		E^2		Control	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Gender												
Boy	28	45.2	32	50.8	20	35.1	21	36.2	38	55.9	27	41.5
Girl	34	54.8	31	49.2	37	64.9	37	63.8	30	44.1	38	58.5
Home language												
Spanish	61	98.4	57	90.5	48	85.7	47	87.0	55	80.9	60	92.3
Other	1	1.6	6	9.5	8	14.3	7	13.0	13	19.1	5	7.7
Language proficiency												
Beginner	62	100	62	98.4	48	84.2	43	81.1	16	23.5	24	36.9
Intermediate	0	0	1	1.6	9	15.8	8	15.1	44	64.7	36	55.4
Early advanced	0	0	0	0	0	0	2	3.8	8	11.8	5	7.7
Achievement												
Low	24	38.7	30	47.6	18	30.5	22	41.5	7	10.3	28	43.1
Average	28	45.2	22	34.9	26	44.1	20	37.7	41	60.3	25	38.5
High	10	16.1	11	17.5	15	25.4	11	20.8	20	29.4	12	18.5
Reading ability												
Low	42	67.7	40	63.5	20	35.1	31	58.5	16	23.5	32	49.2
Average	6	9.7	12	17.0	22	38.6	12	22.6	27	39.7	22	33.8
High	11	17.7	11	17.5	15	26.3	10	18.9	25	36.8	11	16.9

Abbreviations: E^2, Engineering Everything Intervention; *N*, cell sample size.

TABLE A2 Science and engineering learning assessment (SELA) sample size and descriptives (SD)

	Treatment			Control		
	Boy	Girl	Total	Boy	Girl	Total
Kinder[a]	28	34	62	32	31	63
Grade 1[b]	20	33	53	18	30	48
Grade 2[c]	32	26	58	26	38	64
Kinder pretest	8.89 (2.53)	8.94 (1.65)	8.92 (2.08)	8.87 (2.10)	9.16 (3.23)	9.00 (2.69)
Kinder posttest	11.89 (1.64)	11.79 (1.39)	11.84 (1.50)	7.63 (3.23)	8.97 (2.79)	8.27 (3.07)
Grade 1 pretest	8.50 (2.37)	8.61 (2.09)	8.57 (2.18)	6.94 (1.96)	7.53 (2.56)	7.31 (2.34)
Grade 1 posttest	10.60 (1.98)	11.24 (2.19)	11.00 (2.12)	6.94 (1.39)	8.43 (1.81)	7.88 (1.81)
Grade 2 pretest	10.78 (2.28)	11.27 (2.63)	11.00 (2.44)	8.77 (2.76)	9.00 (2.85)	8.91 (2.79)
Grade 2 posttest	13.19 (1.93)	13.58 (2.47)	13.36 (2.17)	9.62 (2.89)	9.39 (2.84)	9.48 (2.84)

Note: $n^a = 125$; $n^b = 101$; $n^c = 122$.

TABLE A3 Technology assessment sample size and descriptives (SD)

	Treatment			Control		
	Boy	Girl	Total	Boy	Girl	Total
Kinder	28	34	62	32	31	63
Grade 1	19	35	54	18	29	47
Grade 2	32	26	58	22	38	60
Kinder pretest	10.32 (3.83)	9.74 (3.18)	10.00 (3.47)	11.59 (3.54)	11.61 (3.66)	11.60 (3.57)
Kinder posttest	16.89 (4.15)	17.21 (4.10)	17.06 (4.09)	13.34 (4.03)	11.90 (3.58)	12.63 (3.85)
Grade 1 pretest	10.21 (2.80)	9.69 (2.70)	9.87 (2.72)	10.28 (3.16)	10.31 (3.13)	10.30 (3.11)
Grade 1 posttest	13.00 (4.01)	13.57 (3.55)	13.37 (3.69)	9.33 (2.72)	9.62 (3.40)	9.51 (3.13)
Grade 2 pretest	13.45 (3.52)	15.22 (4.61)	14.25 (4.11)	12.86 (5.68)	11.39 (4.02)	11.93 (4.70)
Grade 2 posttest	16.79 (3.44)	18.85 (3.24)	17.72 (3.48)	11.86 (4.73)	13.45 (4.25)	12.87 (4.46)

Note: Numbers in parentheses are standard deviations.

TABLE A4 Engineering identity development survey (EIDS) sample size and descriptives (SD)

	Treatment			Control		
	Boy	Girl	Total	Boy	Girl	Total
Kinder	28	34	62	32	31	63
Grade 1	19	35	54	19	29	48
Grade 2	33	29	62	23	36	59
Kinder pretest	50.04 (7.92)	51.94 (7.91)	51.08 (7.91)	50.94 (6.97)	52.68 (4.09)	51.79 (5.76)
Kinder posttest	58.18 (2.00)	57.56 (2.72)	57.84 (2.42)	53.94 (4.77)	51.71 (2.55)	52.84 (3.97)
Grade 1 pretest	55.53 (8.21)	54.20 (5.71)	54.67 (6.65)	52.00 (6.13)	52.93 (6.55)	52.57 (6.34)
Grade 1 posttest	58.84 (2.24)	56.77 (4.75)	57.50 (4.15)	52.37 (5.94)	54.43 (7.44)	53.63 (6.90)
Grade 2 pretest	51.76 (5.25)	54.24 (4.44)	52.92 (5.01)	52.00 (6.08)	54.72 (4.36)	53.66 (5.23)
Grade 2 posttest	54.76 (6.16)	55.45 (4.68)	55.08 (5.48)	50.09 (7.14)	50.72 (9.12)	50.47 (8.34)

Note: Numbers in parentheses are standard deviations.

TABLE A5 Fidelity mean scores for each instructional move by grade level

	Kindergarten			First grade			Second grade		
Instructional moves	K1	K2	K3	F1	F2	F3	S1	S2	S3
Book reading sessions									
1. Provides background information prior to the book reading	3.7	3.5	4.0	4.0	3.7	4.0	4.0	3.3	3.7
2. Asks questions intended to promote understanding of the material	4.0	4.0	3.7	3.8	4.0	4.0	4.0	4.0	3.3
3. Asks questions intended to provide linkages between the content and children's experiences	3.7	4.0	3.3	4.0	4.0	3.7	3.7	4.0	4.0
4. Scaffolds connections between the reading and children's experiences with the engineering activities	4.0	3.7	4.0	3.8	4.0	4.0	4.0	4.0	3.8
5. Emphasizes new science vocabulary with active engagement strategies (cue cards, pair share)	4.0	3.3	3.0	3.7	3.7	3.7	3.3	3.0	3.0
6. Acknowledge and responds to children's questions or comments	3.7	4.0	4.0	3.7	3.8	3.3	3.8	4.0	4.0
7. Acknowledge and responds to children's interest and engagement during the reading	3.3	3.5	4.0	3.0	3.3	3.0	4.0	3.8	3.8

TABLE A5 (Continued)

Instructional moves		Kindergarten K1	K2	K3	First grade F1	F2	F3	Second grade S1	S2	S3
Academic conversations modeling										
8.	Reviews appropriate conversation behaviors (e.g., eye contact, knee-to-knee, etc.)	4.0	4.0	3.7	4.0	3.7	3.7	3.3	3.3	2.7
9.	Reviews targeted conversation skills (rephrasing, building on, etc.)	3.7	3.3	3.7	4.0	3.7	3.7	3.7	3.3	3.0
10.	Scaffolds conversation tasks (sentence starters, concept map, questioning) to support disciplinary communication	4.0	4.0	4.0	3.7	4.0	4.0	4.0	3.7	3.7
11.	Monitors the quality of the conversation	3.7	3.3	3.7	3.3	4.0	3.8	3.8	4.0	3.8
Engineering design process										
12.	Integrates the engineering design process features (ask, imagine, plan, etc.) into the lesson with cultural connections	3.3	4.0	3.3	3.3	3.5	3.5	4.0	4.0	3.3
13.	Scaffolds the engineering process (visual scaffolds, guiding questions, lists, etc.)	3.7	3.7	4.0	4.0	3.7	3.7	3.7	3.3	3.7
14.	Provides opportunities to execute and/or improve the plan[a]	2.3	2.3	2.4	2.0	2.0	2.3	2.5	2	2

Abbreviations: K, kindergarten; F, first grade; S, second grade.
[a]Lower means across three observation periods are expected as one of the three lessons did not involve direct execution of an engineering plan.

TABLE A6 Repeated measures analysis of variance[a] for science and engineering learning assessment (SELA) results

Effect	SS	df	*F*	*p*	n^2_p
Kindergarten[a]					
Intercept	2521.26	1	340.71	.000	0.740
Achievement	50.99	1	6.89	.010	0.054
Group	176.68	1	23.88	.000	0.166
Gender	6.10	1	0.824	.066	0.007
Group * Gender	3.55	1	0.480	.090	0.004
Error	888.01	120			
Grade 1[b]					
Intercept	13,990.02	1	2497.33	.000	0.963
Group	244.34	1	43.62	.000	0.310
Gender	23.61	1	4.21	.043	0.042
Group * Gender	5.22	1	0.932	.037	0.010
Error	537.28	97			
Grade 2[c]					
Intercept	27,237.63	1	734.53	.000	0.863
Group	538.54	1	52.01	.000	0.306
Gender	2.93	1	0.283	.096	0.002
Group * Gender	2.80	1	0.270	.004	0.002
Error	1221.79	118			

Note: $n^a = 125$; $n^b = 101$; $n^c = 122$; Group = treatment group.
Abbreviations: df, degrees of freedom; F, F statistic; n^2_p, partial eta squared; P, p value; SS, sentence starters.
[a]Analysis of covariance was implemented for kindergarten analysis.

TABLE A7 Repeated measures analysis of variance[a] for technology assessment results

Effect	SS	df	F	p	n^2_p
Kindergarten[a]					
Intercept	5059.17	1	314.60	.000	0.724
Achievement	35.32	1	2.20	.041	0.018
Group	118.62	1	7.38	.008	0.058
Gender	14.83	1	0.922	.039	0.008
Group * Gender	11.27	1	0.701	.004	0.006
Error	1929.78	120			
Grade 1[b]					
Intercept	21,600.18	1	1484.93	.000	0.939
Group	140.05	1	9.63	.003	0.090
Gender	0.392	1	0.027	.070	0.000
Group * Gender	0.218	1	0.015	.003	0.000
Error	1410.99	98			
Grade 2[c]					
Intercept	46,617.62	1	1741.22	.000	0.938
Group	781.67	1	29.20	.000	0.201
Gender	55.98	1	2.09	.051	0.018
Group * Gender	49.65	1	1.86	.076	0.016
Error	3105.95	116			

Note: $n^a = 125$; $n^b = 101$; $n^c = 117$; Group = treatment group.
Abbreviations: df, degrees of freedom; F, F statistic; n_p^2, partial eta squared; P, p value; SS, sentence starters.
[a]Analysis of covariance was implemented for kindergarten analysis.

TABLE A8 Repeated measures analysis of variance[a] for engineering identity development survey (EIDS) results

Effect	SS	df	F	p	n^2_p
Kindergarten[a]					
Intercept	93,296.87	1	3261.39	.000	0.965
Achievement	210.26	1	7.35	.008	0.058
Group	250.47	1	8.76	.004	0.068
Gender	0.084	1	0.003	.057	0.000
Group a Gender	38.45	1	1.34	.049	0.011
Error	3432.78	120			
Grade 1[b]					
Intercept	571,385.05	1	10,946.94	.000	0.973
Group	553.60	1	10.61	.002	0.097
Gender	0.476	1	0.009	.024	0.000
Group a Gender	122.33	1	2.34	.029	0.023
Error	5167.39	99			
Grade 2[c]					
Intercept	659,916.06	1	13,927.85	.000	0.992
Group	279.49	1	5.84	.017	0.048
Gender	156.82	1	3.31	.071	0.028
Group a Gender	0.123	1	0.003	.059	0.000
Error	5543.58	117			

Note: $n^a = 125$; $n^b = 101$; $n^c = 121$; Group = treatment group.
Abbreviations: df, degrees of freedom; F, F statistic; n_p^2, partial eta squared; P, p value; SS, sentence starters.
[a]Analysis of covariance was implemented for kindergarten analysis.