Paper ID #17742

Inquiry, Talk, and Text: Promising Tools that Bridge STEM Learning for Young English Language Learners

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Inquiry, Talk, and Text: Promising Tools that Bridge STEM Learning for Young English Language Learners (Fundamental)

Abstract

Little is understood about how young English language learners (ELLs) respond to engineering-centered literacy and design activities and whether that response ultimately leads to content understanding. This study is part of a larger investigation targeting engagement, learning, and identity development of primary English language learners (ELLs) during a five-day engineering unit. Specifically, kindergarten, first and second grade students were examined from twelve classrooms such that 12 teachers and 220 students participated in this study. The research examined the following question: *to what extent does the use of engineering centered activities emphasizing academic conversations during age appropriate tasks lead to increased knowledge of technology and the engineering design process for linguistically diverse students.* The view of engineering learning taken here emphasizes processes (or antecedents to learning outcomes) as well as products of instruction (conceptual understanding and achievement). One implication of this domain specific approach is that instruction should focus on helping students acquire the core ideas and ways of thinking central to a particular domain of knowledge. Consistent with this learning perspective, the extent to which an emphasis on joint negotiation practices (i.e., academic conversations) during hands-on design and literacy activities increased student learning was investigated. To answer the research question, a 2 (group: trained and control) by 3 (time: prior to intervention, immediately after intervention, one week after intervention) repeated measures analysis of variance (ANOVA) was conducted for each grade level separately. The repeated measures Analysis of Variance revealed significant results with low to moderate effect sizes. Learning gains were observed for ELLs who received engineering-centered literacy

activities. These results provide preliminary evidence of the impact of the integration of academic conversation, and narrative texts to improve student learning. Given the cultural and linguistic background of these ELLs, the results reveal the potential for these instructional strategies to promote broader STEM participation.

Introduction

Despite the call for integration of engineering content in K-12 education by the reform movement that fashioned the Next Generation Science Standards [1], there is limited research in effective engineering education practices for primary students. Early childhood education experts argue that very young children can and should be acquiring knowledge that provides the foundations for later STEM learning [1]. Yet the great majority of engineering education research targets secondary and college-level students. This study is part of a larger investigation targeting engagement, learning, and identity development of primary English language learners (ELLs). In order for students to develop a positive engineering identity, sustained engagement in age-appropriate tasks is necessary for learning complex engineering concepts and skills [2].

Theoretical Framework

Learning Perspective. The view of engineering learning taken here emphasizes processes (or antecedents to learning outcomes) as well as products of instruction—conceptual understanding and achievement [3]. Learning is viewed as a *process* of domain-specific knowledge construction and grounded in research on human cognition and cognitive development [4, 5] which views children as active learners [6, 7]. Domain-specific approaches contend that learning in conceptual domains such as engineering is characterized by the development of distinct domain-specific conceptual structures and processes (see [8, 9]).

One implication of this domain specific approach is instruction should focus on helping students acquire the core ideas and ways of thinking that are central to a particular domain of knowledge. However, much of the research on domain specific theory has assumed learning resides solely in the ‘head’ of the learner. Research in the learning sciences has demonstrated the importance of the social nature of human learning, particularly reasoning and problem solving [8, 10]. Therefore, understanding involves socially negotiated and situated learning in specific cultural contexts and practices [9, 11-13]. These perspectives are consistent with scholarship in the area of science and engineering studies, which suggests that scientific knowledge and practice are grounded in and shaped by particular socio-historic contexts (see [8, 14]). Consistent with this learning perspective, we investigated the extent to which an emphasis on joint negotiation practices (academic conversations) during hands-on design and literacy activities increased student learning.

Research in Early Engineering Education

Engineering-centered Literature. Using engineering-centered literature to address disparities in access and exposure to STEM content has been shown be a transformative approach to combatting the trend that students’ interest in science declines after elementary school [15-17]. Previous work has not focused on the literacy component of engineering education but has included hands-on design challenges and involved older elementary students [18-20]. In kindergarten contexts literacy includes texts, conversations, and active experiences that build on ideas, topics and vocabulary grounded in texts read in class [21].

Out past work demonstrated that engineering-centered literacy practices increased and maintained kindergarten-aged students’ engagement [3]. Consistent with past research in reading comprehension [10, 22], we found that engagement was enhanced when a combination of visual, auditory and/or tactual modalities was provided to kindergarten students. The current study was designed to test the extent to which the increased engagement resulting from the combination of activities over multiple days leads to enhanced learning.

Academic Literacy & Text Types. Since the target population for this study is very young elementary students, the narrative structure can engage students in discussions about engineering problems in age-appropriate ways. From a constructivist learning perspective, narrative texts are more age-appropriate than informational texts in that very young students are more familiar with stories than texts that present explanations or scientific descriptions. Thus, it allows teachers to start with what young students already know. However, from a language learning perspective, narrative texts are comprised of syntactic structures different from informational texts and therefore do not model the discourse of the discipline [23]. Thus, an additional aim of this study was to determine if the use of narrative structure providing the broader context of the targeted content and a natural point of entry into the culture of a new discipline can support learning of engineering content.

Specifically, we explored the use of academic conversations to bridge the use of narrative structure to facilitate prior knowledge and to scaffold engineering content, vocabulary, and discourse more germane to the language of engineering [24]. These instructional techniques build on past research in classroom discourse and cooperative learning [25-29]. The goal of academic conversations is to improve productive conversations with students that promote content vocabulary and understanding. Academic conversations are also ideal for the target age group since their literacy skills are still emerging. However, few studies have targeted kindergarten students and we are not aware of published work that investigates the use of academic conversations in early engineering education contexts.

This study explored children's learning over time as a result of exposure to an engineering-centered intervention that supports science and engineering learning and features engineering story books and academic conversations with teachers and peers as they are presented with a well-established hands-on engineering education model (e.g., Engineering is Elementary (*EiE*) unit; Museum of Science [30]). The research presented here examines the following research question: *To what extent does the use of engineering-centered activities emphasizing academic conversations during age appropriate tasks lead to increased knowledge of technology and the engineering design process for linguistically diverse kindergarten, first and second grade students?*

Methodology

Sample & Design

Teachers. Twelve teachers from two mid-sized school districts and four diverse schools in a semi-rural city in the Texas south plains participated in the study. Six of these teachers were trained on the engineering-centered activities (trained teachers) and six teachers were not (control teachers). These teachers had an average teaching experience of 8.53 years and 8.56 for treatment and control respectively. Three of the 12 teachers had prior experience in this approach as they were part of the development of the activities for this study. These teachers were part of the trained group. Each of the two teacher groups were further divided into three grade levels with two teachers at each grade level (K, 1, 2). Table 1 presents the study design with sample sizes by grade level and condition.

Table 1. Sample Sizes and Design

Condition	Grade Level K	1	2	Total
Trained Teachers (6)	43	37	32	112
Control Teachers (6)	34	41	33	108
Total	77	78	65	220

Note: Numbers in parenthesis indicate sample size.

Three of the four schools had 80%-90% of the student population classified as Hispanic, in these schools ELLs represented 30-50% of the student population. One school was comprised of 60% Hispanic and 15% ELL. Two of the schools with high Hispanic populations are identified as under-performing by the state accountability system. One is a high performing school with distinguished status in reading and mathematics. One consistently performs at just above district and state averages.

Procedures

Training & Lesson Planning. Teachers participated in a one-day training session that targeted specific features of the engineering-centered activities including: (a) a read-aloud of an engineering story book (*Engineering Elephants*) as the hook to an inductive technology lesson, (b) the use of an Engineering is Elementary (*EiE*) unit on agricultural engineering, and (c) modeling and guidance of academic conversations with students. The research team demonstrated the lessons teachers were to enact with their students. Evidence of training effectiveness was collected but omitted due to space constraints.

Intervention Activities. The treatment unit took five days to complete. The first three days of the intervention introduced students to technology and engineering with the use of narrative texts that scaffold the engineering content. The last two days involved both hands-on inquiry and engineering design activities. Academic conversations were conducted on each day of the treatment. Details of instruction for each day of the treatment are summarized in Table 2.

Table 2. Description of Engineering-Centered Activities

Day	Description
1	*Picture Read Aloud & Design Sketch:* Teachers read a picture book and engage students in a hands-on sketching activity to activate thinking about technology in relation to the work of engineers. *Technology in a Bag:* Teachers complete a hands-on activity aimed at deepening students' understanding of technology and develop a student generated definition of technology. Students then read *Engineering Elephants*. Students are engaged in two academic conversations. One to practice conversation behaviors (eye contact, turn taking etc), one to develop their understanding of technology.
2	*Storybook Read Aloud:* Teachers present a story that introduces the field of agricultural engineering, the engineering design process, and the real world context of the design task implemented on Day 5. Teachers use visuals while reading the story and manipulate picture cards to draw attention to key events. Students are engaged in two academic conversations: one that develops story vocabulary and one that develops their understanding of agricultural engineering from the context of the story.
3	*Engineering Narrative Video:* Teachers present a video-taped animated play showing a farming problem that needs to be solved using Integrated Pest Management. The video was developed with Buddy Poke iPad App using a modified version of the written play in the *EiE* unit. Teachers manipulate picture cards to draw attention to key events. Students are engaged in two academic conversations: one to deepen their understanding of the design process and one that focuses their attention on the role insects play in natural systems.
4	*Hands-On Inquiry Activities:* Students explore pollination materials, conduct controlled experiments and observe and compare the efficacy of different materials to solve the farming problem posed on Day 3. Students test materials to make decisions about which materials work best in pollination. Students are engaged in one academic conversation to solidify their understanding of the materials based on the results of their experiments.
5	*Engineering Design Task.* Students use their understanding of pollination, materials and their properties, and the design process to design and improve a hand pollinator for a specified flower. Students are engaged in one academic conversation to help them understand links between science, engineering and technology.

Control Activities. Control teachers followed the regular science curriculum. This included teacher directed whole group discussions and opportunities to engage in oral communication with their peers after Think-Pair-Share prompts (e.g., tell your partner what type of flower this is) were provided to students. Control teachers engaged students in group tasks that involved some manipulation of concrete objects. For example, the use of real plants to demonstrate parts of the plant. Teachers asked questions that required students to observe the plants, they also rephrased student responses. Control teachers closed the lessons on days of the study period with a teacher-directed review of the content.

Instruments

Two instruments targeting technology and engineering design knowledge were administered prior to the start of the treatment (Time 1), on the last day of the treatment (Time 2, Day 5) and one week after the treatment ended (Time 3).

Engineering & Science Learning Assessment. To measure learning of the engineering design process, the Engineering Design Assessment (EDA) was developed by the research team. The EDA consists of 8 items: two items assess children's understanding of scientific inquiry processes and 6 items assess their understanding of engineering design. Items follow a format in which the child is shown three pictures and asked a question about these pictures that could be answered verbally or by pointing to the correct pictures. Both control and trained teachers administered this assessment to their students.

Technology Assessment. The technology assessment contained two parts. In the first part, students were presented with pictures of 20 items. Students were instructed to circle the items that represented technology items. Students were given a point for correct identification of items as examples or non-examples. Thus, totaling 20 points in this section. In the second section, students were asked to define technology. Responses to these items were scored on a 3 point scale from "0" representing incorrect definition, to "2" representing a more complete and elaborated definition such as "something that is human made and solves a problem." Three graduate assistants scored student responses. Kappa coefficient was calculated on rater agreement and indicates strong agreement among the raters (K = .85). Scoring is not yet complete and will be reported on if accepted.

Results

To answer the research question, a 2 (Group: trained, control) X 3 (Time: Time 1, Time 2, Time 3) repeated measures analysis of variance (ANOVA) was conducted for each grade level separately. Tables 3 and 4 present descriptive statistics and show that the means for students in the trained teachers' classrooms increased significantly immediately after the treatment (Time 2). The means for the control group also increased for kindergarten and first grade but the increases were not significant. More importantly the means show that these increases were still present and significant one week after intervention. This was not the case for any of the control group means. Figure 1 presents these trends graphically as well as reveal the interaction effects presented in Table 5. In every case, the control group means dropped more drastically one week after the treatment (Time 3) than the treatment groups. For the technology assessment, Time 3 means for all grade levels indicate that technology knowledge effect was still present at Time 3.

For the EDA, the first and second grade Time 3 means indicate that the engineering learning was maintained one week later.

Table 3. Technology Knowledge Descriptive Statistics

	Time 1		Time 2		Time 3	
Variable	M	SD	M	SD	M	SD
			Kindergarten			
Treatment (43)	9.12	2.74	15.84	3.88	15.49	3.88
Control (34)	10.74	2.84	12.35	4.05	12.35	4.19
			First Grade			
Treatment	10.73	2.82	17.11	2.95	15.49	4.44
Control	10.12	3.04	12.24	3.11	12.95	3.93
			Second Grade			
Treatment	8.44	1.54	13.63	3.20	13.78	3.20
Control	10.27	2.41	10.61	2.18	11.67	3.39

M = mean; SD = standard deviation

Table 4. Engineering Design Knowledge Descriptive Statistics

	Time 1		Time 2		Time 3	
Variable	M	SD	M	SD	M	SD
			Kindergarten			
Treatment (43)	4.65	1.56	5.42	1.58	4.91	1.66
Control (34)	3.88	1.89	4.18	1.46	3.09	2.11
			First Grade			
Treatment (41)	4.95	1.07	5.98	1.08	5.20	1.68
Control (37)	4.35	1.48	4.84	1.76	3.54	2.23
			Second Grade			
Treatment (32)	5.91	1.38	6.69	.82	6.20	1.49
Control (34)	5.72	.80	6.06	1.13	4.91	1.44

Table 5. Repeated Measures ANOVA by Grade Level.

Effect	*MS*	*df*	*F*	*p*	η^2
		Kindergarten			
Time	417.48	1.99	50.24	.000	.400
Time x Group	159.34	1.99	19.18	.000	.204
Error	8.31	149.27			
		First Grade			
Time	454.98	1.86	49.65	.000	.395
Time x Group	415.66	1.86	22.77	.000	.230
Error	9.16	141.46			
		Second Grade			
Time	203.44	1.94	28.61	.000	.312
Time x Group	94.40	1.94	13.28	.000	.174
Error	7.11	122.34			

Figure 1. Technology& Engineering Design Knowledge Means by Time for Each Grade Level

Conclusion & Significance of Study

One of the persistent instructional challenges teachers working with ELLs face is their meaningful integration into learning activities [31]. This study explored the extent to which a combination of activities developed with the learning and developmental needs of early elementary ELLs in mind. We integrated routines for academic conversations into hands-on literacy and engineering-centered inquiry activities. The analysis revealed significant results with low to moderate effect sizes. These results provide preliminary evidence of the impact of the integration of academic conversation to improve student learning. Transcripts of student discussion are currently being analyzed and will be used to show what science vocabulary and discourse patterns are evident in group activity to understand more fully how this treatment supports ELL learning. The observed trends is promising for teachers with ELLs in their classrooms. Given the cultural and linguistic background of these ELLs, the results reveal the potential for these intervention strategies to promote broader STEM participation. This study is significant as it is the first empirical study of the impact of academic conversations on student learning in a STEM discipline; it also uniquely targets learning of early elementary ELLs in engineering education.

Acknowledgements

We gratefully acknowledge support by a grant from the National Science Foundation under contract DRL-12487, and encouragement from our program manager, Dr. Edith Gummer. Texas Tech University IRB number for this project is 504973.

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