Ready and Waiting: How Cambodian Primary Students' Self-perceived Skills and Aspirations are Primed for the Field of Engineering

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Abstract: A project-based engineering education unit was implemented in a primary school in Cambodia. An effectiveness study was conducted to investigate students' attitudes and expectations of engineering as a profession and students' self-perceived 21st century skills. The findings revealed that prior to the curriculum implementation both male and female students had positive attitudes toward engineering, positive beliefs toward the role of engineering in their lives, and highly favorable perceptions about their perceived 21st century skills. Results indicated no significant increase in overall students' attitudes and expectations of engineering, or self-perceived 21st century skills. Yet, students who had an average mean score of less positive feelings on the pre-assessment showed significant increases in their attitudes and expectations toward engineering, as well as their self-perceived 21st century skills. These findings indicate that students at the primary level in Cambodia are either already enthusiastic about engineering or are significantly more so once exposed to an engineering curriculum. The importance of incorporating engineering principles into the Cambodian curriculum are discussed.

Keywords: engineering education; 21st century skills; Cambodia; curriculum reform; developing country context

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The severe underrepresentation of Cambodian students entering engineering fields is of significant concern, as engineering is one of the fastest growing sectors in the Southeast Asian region, with average growth rates of over 20 percent (Association of Southeast Asian Nations [ASEAN], 2007). With more developed nations in the region dominating the professional job market, Cambodians face the risk of underrepresentation in local and regional engineering projects and positions due to a lack of qualified human resources to support competition for economic and human resources development (ASEAN, 2007; United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2010). HRINC (2010) reported that less than four percent of Cambodian students enrolling in higher education select engineering as a major. As engineering projects and employment positions continue to dominate the national and regional job market, promoting educational opportunities for students to engage in engineering practices is of the utmost importance (ASEAN, 2007; UNESCO, 2010).

Little is known about factors contributing to the underrepresentation of students in engineering majors in higher education in Cambodia. The lack of educational research in Cambodia, as is the case in many developing countries around the world, exemplify the need for further exploration of the factors contributing to the lack of students pursuing engineering as a career. It is widely known that exposure to engineering in K-12 education in developed nations is strongly correlated with increases in students enrolling in engineering majors in higher education (Palmer, 1997). While engineering education initiatives are abundant in education systems in developed countries, there is a remarkable lack of information documenting, explaining, or analyzing engineering education in less developed education systems such as Cambodia's.

While the Cambodian education system continues to rebuild from the mass destruction of human and physical resources during the Khmer Rouge (1975-1979) and decades of subsequent social, political, and economic unrest, little is known about how to promote early engineering interests in a nation that has yet to gain momentum in the field. Faced with a lack of resources and highly-qualified teachers, the Cambodian national education system has yet to implement widespread initiatives to meet international standards for curriculum, instructional practice, and school resources in science, technology, engineering, and mathematics (STEM) content areas (Ministry of Education, Youth, and Sport [MoEYS], 2015, 2010; United States Agency for International Development [USAID], 2010). While science, math, and technology have some presence in the Cambodian national curriculum, there is no nationally-required curriculum that addresses engineering concepts or design processes in K-12 education (MoEYS, 2015). Although no research has yet been conducted to estimate the impact of this deficit in Cambodia or other developing country contexts, the lack of engineering in the curriculum may be a contributing factor to the low rates of youth in Cambodia and other developing contexts entering engineering majors in higher education institutions.

In order to investigate the mitigating factors surrounding student perceptions of engineering as a viable career path, this study focused on the impact of an engineering curriculum experience at the primary school level. Primary level engineering curriculum has potential to enhance STEM learning and achievement, promote the understanding of and abilities of engineering design, and increase awareness of the work of engineers (National Research Council, 2009). Given this implication and the demonstrated lack of engineering education in Cambodia and other developing country contexts, this study investigated the impact of an engineering-specific extracurricular curriculum unit on primary school students' perceptions of interest in engineering fields and their personal assessment of skills related to engineering careers.

Theoretical Framework and Review of Relevant Literature

Engineering Education in Primary Schools

Although little is known as to the efficacy of engineering education in primary schools in Cambodia, engineering education in the Western context can increase learning and achievement in science and mathematics (National Research Council, 2009). In particular, project-based learning environments have been shown to significantly increase students' content knowledge and motivation to learn (Bielefeldt, Paterson, & Swan, 2010; Cejka, Rogers & Portsmore, 2006). Self-efficacy along with exposure to content at early grades may influence the later choices and transition of youth into the labor market, and initiatives in engineering education worldwide have been developed based on this evidence (Cantrell, Pekcan, Itani & Velasquez, & Bryant, 2006). Engineering curricula can foster a comprehensive approach for students to implement problem solving strategies both inside the classroom, and in contexts in their daily lives outside the classroom (Brophy, Klein, Portsmore, & Rogers, 2008; Diaz & Cox, 2012). Universally accepted engineering design principles, intrinsic to engineering education, can contribute to the development of project-based curricula that promote interest at the primary level. Such curricula may provide for purposeful, systematic, collaborative, and creative approaches to learning (National Research Council, 2009).

Project-based learning and engineering education. Project-based learning provides students the opportunity to connect their current knowledge with new information in an exploratory way that is driven by the student and their formation of knowledge. This has been proven successful in classrooms around the world when lessons are student-centered and inquiry-based (Chu, Tse, & Chow, 2011; Smith, Sheppard, Johnson, & Johnson, 2005). The key to student-centered learning is the switch from the teacher providing necessary materials for learning content, and instead giving the students the necessary skills and resources to examine the materials for themselves, learning through exploration (Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991; Krajcik & Blumenfeld, 2006; Thomas, 2000). Project-based learning involves students engaged in producing collaborative products. Student learning activities may involve pursuing solutions to problems, designing plans and/or experiments, testing designs, collecting and analyzing data, drawing conclusions, and communicating their ideas and findings to others (Kraijcik & Blumenfeld, 2006). Project-based learning promotes an environment in which students take charge of their learning and the teacher takes on a supportive role (Reid, 1987). This environment provides both the nurturing of social-emotional development of students while encouraging them to think critically about their learning.

Engineering education and students' self-perceived skills. Prior studies of engineering education in primary school classrooms have reported that project-based learning using engineering design principles improved student learning in other STEM content areas and also increased student interest in engineering careers (National Research Council, 2009; Woolnough, 1993). The incorporation of engineering education into primary school education can function as a catalyst for fostering cognitive development to enhance communication, collaboration, critical thinking, and creativity- commonly known as 21st century skills (Rogers & Portsmore, 2004; Zarske, Ringer, Yowell, Sullivan & Quiñones, 2012). These skills provide students with a toolkit and strategies that enhance creativity and innovation (Dede, 2010; Klein & Sherwood, 2005; National Academy of Engineering & National Research Council, 2014; Partnership for 21st Century Skills, 2009).

Curriculum learning experiences that incorporate engineering design may afford students the opportunity to enhance 21st century skills development using a project-based learning approach. While the integration of engineering education into primary schools has shown significant improvements in student awareness of engineering design in developed countries such as the United States (Lachapelle & Cunningham, 2010), researchers have yet to explore the impact of a project-based learning approach using engineering design principles to enhance 21st century skills in a developing country such as Cambodia.

Engineering education and student attitudes. The incorporation of engineering design and practices into pre-existing curricula to enhance both project-based learning and student-centered learning inherently involves high-quality pedagogical practices (Brophy et. al., 2008; Cunningham & Lachapelle, 2010). Student-centered engineering education necessitates experiential learning in which teachers purposefully engage with learners in direct experience and focus reflection in order to increase knowledge, develop skills, and clarify values (Estes, 2004). While specific learning objectives may differ, the overarching purpose of experiential learning environments include student personal growth, critical thinking, and a better understanding of the global impacts of school and social constructs (Breunig, 2005; Brookfield, 1996; Christian, 1999).

In developing community or country contexts, teaching engineering using an experiential approach can provide students with the opportunity to apply curriculum and content to real-world contexts. Constructivist theories of education acknowledge the importance of a child-centered curriculum that promotes assimilation of new experiences into pre-existing knowledge frameworks, based on how the student's internalization of new information fits into current schemas (Moreno, Gonzalez, Castilla, Gonzalez & Sigut, 2007; Piaget, 1952). When new information challenges pre-existing understanding of concepts, students use accommodations to reframe their understanding of information or form new ideas about how the world around them functions (Piaget, 1952). The social and environment contexts in which students are exposed to these learning opportunities are important factors in cognitive development and development of positive attitudes (Johri & Olds, 2011; Vygotsky, 1967). Rooted in these beliefs regarding construction of knowledge, project-based learning fosters the development of 21st century skills and allows students to formulate their own understanding of engineering concepts, rather than a pre-constructed view in a teacher-driven curriculum (Johri & Olds, 2011; Myers & Berkowicz, 2015).

Engineering education and student expectations. While constructivist theories have been present in the field of educational research for decades (Papert, 1980; Piaget, 1952; Wenglinsky, 2000), the introduction of project-based learning as a critical element of the constructivist framework is relatively new (Barron et al, 1998; Thomas, 2000; Myers & Berkowicz, 2015). The role of project-based learning in the engineering classroom has been shown to be an effective method for developing and enhancing skills and positive expectations associated with content (Markham, 2011). Positive beliefs regarding content has been shown to be more significant for students who have above-average achievement with classroom content (Caleon & Subramaniam, 2008), yet little is known regarding pre-existing beliefs regarding engineering as a profession and career with students who have no previous exposure to engineering content in the classroom.

Social Constructivism

Social constructivism emphasizes the importance of culture in providing children with cognitive tools needed for development. Within these cultural contexts, it is critically important that experiential learning within authentic environments is related to students' real-world contexts (Hodson & Hodson, 1988; Wertsch, 1997). In the case of Cambodia, many students experience a context very different to those experienced by students in the United States and other developed countries. The ways in which students interact with their teachers, parents, and peers is heavily rooted in Cambodian cultural norms. These cultural norms influence the role of the student in the classroom, especially in regard to student-driven learning. Children are taught to be quiet, listen to their elders, and refrain from questioning authority (Smith-Hefner, 1999). The student in the classroom is taught to listen carefully, respect the teacher, and digest the necessary information to perform well on academic assessments (Eng, 2013).

These cultural norms also play a role in teachers' willingness, capabilities, and training in the classroom. Teachers accustomed to a teacher-centered, didactic learning environment are required to drastically modify their teaching styles in order to accommodate a project-based, student-driven curriculum. While teachers may be open to a change in classroom teaching and learning approaches, the successful enactment of a project-based learning curriculum requires training and support of new pedagogical practices. In addition, continued support and professional development is necessary to ensure sustainability and efficacy of the teaching methods and strategies intrinsic to project-based learning curriculum (Fallik, Eylon, & Rosenfeld, 2008; Marx, Blumenfeld, Krajcik, & Soloway, 1997; Thomas, 2000).

Research Focus

The focus of this study was to understand the impact of an engineering curriculum unit on primary school students within a developing country context. In particular, the dual goals of this research are to measure the impact of engineering education in developing communities on (1) the attitudes and expectations of primary school students regarding engineering as a possible profession in the future, as well as (2) primary students' self-perceived personal and educational qualifications that would make them possible candidates for engineering careers.

To achieve this, a five-day curriculum unit from *Engineering is Elementary* [EiE] (2010) was modified for Cambodian cultural and contextual factors. It was designed to provide primary school students with exposure to a project-based learning environment that incorporated engineering design principles while promoting 21st century skills. This study explores the following research questions:

RQ1: How did participation with the engineering curriculum unit impact Cambodian primary students' self-perceived 21st century skills, attitudes, and expectations toward engineering?

RQ2: How did the adoption of the project-based learning, engineering curriculum unit translate into classroom practice?

Methodology

This study employed a project-based, student-centered instructional unit that created a remarkably different classroom environment than traditional forms of instruction in Cambodian classrooms, which is teacher-centered and didactic in nature. The unit, *Designing Bridges*, was structured to incorporate project-based learning activities to explore the engineering design process and culminated in a final project, building a bridge. The learning activities for each lesson in the engineering unit are presented in Table 1.

Table 1. Scope and sequence of the curriculum unit

Lesson	Learning Activities
1	Students were introduced to engineering design principles through an illustrated storybook set in the Cambodian context. A series of discussion questions before, during, and after the story encouraged students to reflect on the bridges in their local communities. Students then participated in an activity that explored the definition of, and everyday uses of technology.
2	Activities focused on helping students gain a broader perspective on the unit's engineering field of focus. Through hands-on activities (push and pull and impact of force on structures), students learned more about the type of work done by civil engineers, and the kinds of technology they produce.
3	Students created three different types of bridges and analyzed different structures to understand how each is affected by force. Students examined and prepared available local materials (paper, straws, etc.) to design their bridges to make them safe and stable.
4	Students used the engineering design process to design a bridge made from local materials.

5	Students brought their homemade bridges to class and presented their work. Bridges were tested for strength and feasibility. Students engaged in a reflective discussion about their work and engineering as a profession.

Participants

The sample of this study included 68 primary school students (63% female) at one Ministry of Education school in Siem Reap province, Cambodia. The school receives external support and funding through the nongovernmental organization (NGO) Caring for Cambodia. Support included teacher training, health and dental programs, school meal program, and *life skills* training beyond the traditional Ministry of Education programs. This school was purposely selected based on classroom and teacher availability. All students in 4^{th} and 5^{th} grades (ages 9-13) enrolled in the afternoon session at this school were invited to participate in the engineering curriculum unit that was implemented as an extracurricular program.

Two male teachers participated in the study. Both teachers had at least 5 years of teaching experience at the primary level. Neither teacher had taught any type of engineering curriculum in the past. Both attended a series of professional development sessions to become familiar with the modified EiE curriculum unit, the engineering design process, and project-based learning pedagogy that was required for the implementation of the unit. Four, two-hour teacher professional development sessions (8 hours total) were conducted by the first author. Professional development sessions were guided by the EiE professional development guidelines, with modifications to support the adapted version of the curriculum for Cambodian contexts.

Measures

A pre-and post-assessment survey was modified from the EiE sample (to be contextually relevant) and administered to each student participating in the study. The survey included 34 items designed to measure students' overall attitudes and expectations regarding engineering, as well as their self-perceived 21^{st} century skills (see Appendix A). Each item included a four-point rating scale that ranged from 1-4 in which 1 indicated strongly disagree and 4 indicated strongly agree. The total possible scores for the entire survey ranged from 34-136. The survey included three subscales that are described below. The survey was translated from English to Khmer (Cambodian language) by a Khmer translator fluent in both English and Khmer. For validation, the survey was tested with a group of 15 Cambodian students who did not participate in the study. The questions were reviewed for content validity by a STEM education expert and for proper translation by four Cambodian primary school teachers. The reliability (Cronbach's alpha) for the entire survey was .89.

The *Attitudes toward Engineering* subscale included thirteen items that asked students about their perceptions of engineering and how it relates to their perceived skill sets and future jobs aspirations. The scale was adapted from questions from the Trends in International Mathematics and Science Study (TIMSS) student background questionnaire and from a questionnaire in the EiE curriculum materials. For example, items included, "I would like a job that lets me figure out how things work," "I would enjoy being an engineer when I grow up," and "I would like to help plan bridges and tall buildings." Responses ranged from 1-4 in which 1 indicated strongly disagree and 4 indicates strongly agree, thus higher scores reflected the more positive attitudes toward engineering. The total possible scores for this subscale ranged from 13-52. Reliability (Cronbach's alpha) for the *Attitudes toward Engineering* subscale was .76.

The *Expectations regarding Engineering* subscale included a set of eight items, adapted from the Trends in International Mathematics and Science Study (TIMSS) student background questionnaire and EiE. Sample items included: "I would like to learn about engineering because I think it is interesting," "I want to learn about engineering to get a more prestigious job when I grow up," "I will enjoy learning about engineering," and "Engineering education will help me better prepare for what I want to be when I grow up." The response selections for these items were between 1-4, where 1 indicated strongly disagree and 4 indicated strongly agree. Higher scores suggested more positive beliefs toward the role of engineering in students' lives. The total possible scores for this subscale ranged from 8-34. Reliability (Cronbach's alpha) for this subscale was .79.

The *Self-perceived 21st Century Skills* subscale consisted of thirteen items to assess students' perceived 21st century skills. These items were adapted from the TIMSS student background questionnaire. Sample items included: "I like to explore new ways of thinking about solutions to problems," "Working with other people helps me to think creatively," and "Working with others is better than working alone." Responses to these questions ranged from 1-4 in which 1 indicated strongly disagree and 4 indicated strongly agree, thus the higher the scores, the stronger the perceived 21st century skills. The total possible scores for this subscale ranged from 13-52. Reliability (Cronbach's alpha) for this scale was .77.

A *Fidelity of Implementation* observation protocol was adapted from UNESCO's classroom observation protocol for STEM education (Szmodis & Eng, 2014) and Stearns, Morgan, Carparo & Carparo (2012) to ensure that all components of the curriculum were implemented. The protocol included a method to capture the teachers' adherence to using the engineering design process, promoting a learning environment related to 21st century skill-building (communication, collaboration, creativity, and critical thinking), and using problem-based learning. The protocol also included areas for observation notes that focused on the teacher facilitation of the learning environment, use of available resources, formative assessments, student participation, and general teacher and student attitudes in the classroom. After each classroom session, the researcher and teacher would recap the lesson, and the teachers would give their overall impression of the lesson (what was successful and what could be enhanced) and the classroom environment. Ten total observations were conducted, five with each of the two teachers. Observations were conducted by a researcher, who was a non-participatory observer during the curriculum intervention.

Data Analyses

Quantitative data were analyzed using STATA (version 12.0). Part of the data-cleaning process included conducting frequency analysis of all variables. Cronbach's alpha was run for each subscale to confirm internal consistency or scale reliability. Items in the scales were reversed coded as needed. Eight students were dropped from the study due to either a missing pre- or post-assessment. Paired sample *t*-tests were conducted to analyze any mean score differences between pre-survey and post-survey results for each of the three scales: *Attitudes toward Engineering, Expectations regarding Engineering,* and *Self-perceived 21st Century Skills.* Analysis within subgroups (lowest vs. highest performing) between mean scores in the three separate scales were analyzed with paired sample *t*-tests to understand each item's difference between pre- and post-assessment.

Results

The data for both pre- and post-survey data were sorted to only include students who completed both instruments. The paired t-test results for the entire survey and all three scales (*Attitudes toward Engineering, Expectations regarding Engineering, and Self-perceived 21st Century Skills)* did not show significant gains from pretest to posttest (Table 2). The results showed the students had initial positive attitudes toward engineering, positive beliefs toward the role of engineering in their lives, and highly favorable perceptions about their perceived 21st century skills. There was very little difference between the mean scores of the entire survey and the mean scores of each subscale from pre-test to post-test.

There was very little difference between the mean scores of the entire survey and the mean scores of each subscale from pre-test to post-test for the students when grouped by teacher. The results by teacher were not statistically significant, which indicated that the classroom environment and teacher delivery were not distinguishing factors in student responses on the post-survey.

Table 2. Pre- and post-survey survey results for entire survey and for each subscale (N=68)

	Pre-survey mean score (SD)	Post-survey mean score (SD)	*t*
Entire survey results (34 items)	109.23 (11.88)	109.90 (14.25)	-1.04
Attitudes toward Engineering (13 items)	46.03 (4.08)	46.14 (5.84)	1.13
Expectations regarding Engineering (8 items)	26.35 (3.97)	26.25 (3.59)	-0.30
Perceived 21st Century Skills (13 items)	37.96 (4.19)	38.63 (6.10)	0.68

Note: Scale range for each item: 1 = Strongly disagree; 4 = Strongly agree

Although students reported positive attitudes toward engineering before the curriculum implementation, post-survey results indicated that the curriculum was somewhat effective in increasing student interest. For approximately half (47%) of the individual items, post-survey scores were higher than pre-survey scores.

Due to a lack of significant findings from the total survey and subscale results for the entire sample, the student data were further analyzed by each individual teacher to examine if there were significant differences in student scores by teacher. Table 3 displays the paired t-test results for the *Attitudes toward Engineering, Expectations regarding Engineering, and Self-perceived 21st Century Skills* subscales by teacher.

Table 3. Pre- and post-survey results for each subscale by teacher (N=68)

	Teacher 1 (n=34)			Teacher 2 (n=34)		
Subscale	Pre-survey mean score (SD)	Post-survey mean score (SD)	t	Pre-survey mean score (SD)	Post-survey mean score (SD)	t

Attitudes toward Engineering (13 items)	45.0 (4.89)	46.0 (7.02)	0.67	47.12 (5.13)	46.95 (4.69)	-0.12
Expectations regarding Engineering (8 items)	26.25 (3.78)	26.14 (3.85)	-0.13	26.54 (4.20)	26.33 (3.68)	-0.17
Perceived 21st century skills (13 items)	37.23 (4.23)	38.29 (6.47)	0.74	38.91 (4.03)	39.16 (5.67)	0.17

Note: Scale range for each item: 1 = Strongly disagree; 4 = Strongly agree

Due to the negligible findings between the pre-and post-survey scores by the entire sample of students and by each teacher, the group was then divided by pre-test responses to examine the change in students' responses for the lowest pre-survey responders. Because there was a ceiling effect with the data results, the overall results may have been skewed toward higher responses for the entire group. Therefore, we divided the sample into two groups: students who scored a mean average at or above 3.0 on for all pre-test items and those who scored a mean average lower than a 3.0 (2.99 and lower) for all pre-test items. This reference point was chosen due to the construction of the Likert-type scale on the surveys, which indicated a 3.0 or higher as a "more strongly agree" selection while 2.99 and lower indicated a "less strongly agree" selection. Therefore, the groups were separated by those who had an average mean score of more positive feelings toward engineering and their 21st century skills, and those who had an average mean score of less positive feelings. Table 4 displays paired t-test results for all three subscales for *Attitudes toward Engineering, Expectations regarding Engineering, and Self-perceived 21st Century Skills* subscale by the lower average mean score pre-test group.

Table 4. Pre- and post-survey subscale results for the lower average mean score pre-test group (n=33)

Scale	Pre-survey items average mean score (SD)	Post-survey items average mean score (SD)	t
Attitudes toward Engineering (13 items)	2.89 (.40)	3.23 (.50)	2.86***
Expectations regarding Engineering (8 items)	2.87 (.43)	3.22 (.50)	3.01***
Perceived 21st century skills (13 items)	2.90 (.28)	3.31 (.47)	2.86***

***, $p<.001$

The results found that the thirty-three students who scored the lowest on their pre-test measures on all three subscales had significantly higher scores on the post-test for all three scales. These students had significant gains in positive attitudes and expectations toward engineering, as well as significant increases in their self-perceived 21st century skills. These findings confirmed that the data showed a ceiling effect of more positive attitudes, beliefs, and perceptions for the higher scoring students.

Fidelity of Implementation Observations

During the classroom observations, the teachers completed all aspects of the five-day unit of instruction and adhered to all of the components of the engineering design process during the curriculum enactment. Table 5 displays a summary of the classroom observations from the fidelity of implementation protocol that focused on collaboration, communication, critical thinking, creativity, and problem-based learning. There were differences noted for both teachers between days 1-2 and 3-5 of the curriculum implementation. During the first two days of the unit, the teachers did not fully complete each of the project-based learning components, which may have accounted for some delayed understanding of key concepts for the students during the initial part of this intervention. By day three, both teachers included all problem-based learning components. The data revealed that the teachers were facilitating a 21st century skills throughout the entire implementation that focused on creativity, communication, critical thinking, and creativity. Pedagogical implementation was predominantly student-centred with only a few instances of observed didactic instruction used during the curriculum implementation. During the observations, teachers would review the content and objectives of the day's lesson and remind students of classroom rules. Teachers would then allow the groups to work independently, while going from group to group to ensure they were on task and had all of the needed resources. Once the classroom was managed and all students were working on their tasks, both teachers would go from group to group to ask leading questions, talk with students about project objectives, and review content with small groups. There was minimal variability between the teachers regarding their fidelity of implementation, with an average +/- 2% variance between the teachers noted across all observation days on the observation protocol.

During the post-lesson recaps, both teachers reported that the course was much "easier" to teach than a traditional lesson, and much more "fun" for students and the teacher. One teacher commented that he "wished all lessons could be taught like this. It makes teaching so fun and easy. I had no idea students were so creative. They think of things I would never have thought of on my own. They are so smart".

Table 5. Summary of the fidelity of implementation observations for days 1-5 by teacher

	Teacher 1 (n=34)		Teacher 2 (n=34)	
Observation protocol (%)	Day 1-2	Day 3-5	Day 1-2	Day 3-5
Collaboration:				
• Students work in groups	100%	100%	50%	100%
• Students have shared responsibility for group work	100%	100%	100%	100%
• Students appear willing to compromise to accomplish a common goal	60%	100%	80%	100%
Communication:				
• Students articulate thoughts and ideas clearly through speaking and writing	100%	100%	100%	100%
• Students rely on their group to answer questions	60%	66%	40%	66%
• Students use multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and design	80%	100%	10%	100%
Critical Thinking:				
• Students analyze their project and plan projects based on learned content	100%	100%	100%	100%
• Students ask significant questions to identify constraints and find solutions to problems	100%	100%	100%	100%
• Students analyze the data to test the design solutions	100%	100%	100%	100%
Creativity:	100%	100%	100%	100%

• Students demonstrate originality and inventiveness in work				
• Students act on creative ideas	100%	100%	100%	100%
Project Based Learning:				
• The engineering design principles are introduced by the teacher	100%	100%	100%	100%
• teacher models the engineering design process and uses examples appropriate to the cultural context	80%	100%	80%	100%
• teacher scaffolds lesson thorough formative assessments that support student understanding of the engineering design process	60%	100%	60%	100%
• the teacher identified and engaged students with eliciting prior knowledge appropriate to their cultural context	80%	100%	80%	100%

Discussion

A main goal of this study was to measure the attitudes and expectations of primary school students regarding engineering and their self-perceived 21st century skills – important skills that are intrinsic to the engineering field prior to and after completing an engineering curriculum unit. The majority of students reported positive attitudes and expectations regarding engineering as well as high self-perceived 21st century skills both prior to and after the curriculum implementation. The students' pre-existing overall positive attitudes toward engineering were surprising, given the lack of engineering content exposure in the Cambodian curriculum and the fact that there are very few high school graduates entering engineering majors in university settings (HRINC, 2010). Furthermore, the students reported that they had positive attitudes toward the 21st century skills of collaboration, communication, creativity, and critical thinking. These findings suggest that this subgroup of students was primed and ready to explore engineering in greater depth, if given the opportunity.

After controlling for the ceiling effect caused by the students who began the study with strongly positive attitudes, the lower-scoring subgroup on the pre-survey had significant gains in their attitudes and expectations regarding engineering as a profession. These results indicated that the curriculum unit implementation had desirable results for Cambodian students. The findings suggest that the students who used an engineering curriculum that included experiential learning and problem-based learning contexts can have more positive attitudes toward engineering, positive beliefs toward the role of engineering in their lives, and more favorable perceptions about their perceived 21st century skills after using the engineering curriculum in a Cambodian primary school.

Young children are uninhibited in their exploration of possible career interests in primary school, with interests in STEM declining significantly during and after middle school (Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, & Kimmel, 2010). It is at the primary level during students' formation of attitudes and expectations regarding engineering as a possible career choice that educators have the opportunity to expose students to the engineering design principles and help them further cultivate interests in engineering professions. Most children at Cambodian MoEYS schools have neither exposure to engineering design principles, nor are they provided with opportunities to understand the benefits and opportunities that a career in engineering would provide them and their families. As of 2015, Cambodia has a GDP growth rate of 7.2%, compared to 6.3% in Asia as a whole (Asian Development Bank [ADB], 2015). Cambodia is in a phase of rapid growth, which requires a population capable of supporting that growth in a multitude of facets. Because some of Cambodia's strongest growth trends are in industry and services (ADB, 2015), it is of the utmost importance that students are aware of the career options available to them in engineering in the future.

With a national average dropout rate of 31% between primary and lower secondary school, Cambodia struggles with a significant deficit of highly educated human resources. Issues of dropout are prolific and diverse: the need for children to work in order to help the family with immediate needs are one driving force behind student dropout rates. Parents often take their children out of school to help earn money for the family or take care of younger siblings (Smith-Hefner, 1999). Parents are more likely to keep their children in school if they can see education as a long-term investment for the benefit of the entire family. By providing students with engineering education opportunities, there can be a better understanding of how an education can provide students and their families with the depth of knowledge needed to succeed in a 21st century workforce (Brophy et. al., 2008; Linn, 2003).

Due to their lack of exposure to engineering education at the primary level, students in marginalized communities run the risk of falling even farther behind their counterparts in more high-functioning education systems. Not only will learners have fewer opportunities to develop the skills necessary for conceptualizing and constructing innovative engineering design projects (Sadler, Coyle & Schwartz, 2000), but they will miss out on opportunities to further develop their 21st century skills that are widely recognized as critical skills to have in a globally competitive workplace (Partnership for 21st Century Skills, 2009). Research further indicates that primary school students have fewer opportunities than students in lower and upper secondary schools to high-quality mathematics, science, engineering, and technology instruction, even though we know how important this exposure is to their achievement and future interest in STEM fields (Nadelson, Callahan, Pyke, Hay, & Dance 2013; DiFrancesca, Lee, & McIntyre, 2014). Yet, with student interest in the sciences declining significantly by the upper grades, it is imperative to expose primary school students to STEM fields in order to both pique their interest and give them the foundational skills necessary to support them through the school-to-work or school-to-university transitions.

Certain initiatives, as a means of improving STEM education and increasing the number of individuals who enter STEM careers, focus both on K-12 students and teachers. The second goal of this study was to understand how the adoption of the project-based learning, engineering curriculum unit translated into classroom practice. Although the present study included only two teachers, the successful implementation of this engineering curriculum shows promise for further teacher investment and training in engineering instruction using a project-based learning environment in Cambodia. Classroom observations indicated the successful implementation of the curriculum, which proved to be a drastic departure from the typical, didactic teaching styles in Cambodian classrooms. Teachers not only embraced the curriculum, but had positive feedback about teaching in a student-centered classroom environment. Further research is needed to explore the effects of larger-scale teacher professional development in Cambodia and other developing countries that focus on preparing teachers for implementing engineering curriculum designed for local contexts.

Within the Cambodian context, it is assumed that limited exposure to engineering concepts prevents elementary students from developing an accurate understanding of engineering as a field of study and as a career, and therefore prevents them from pursuing careers and university majors in engineering (Capobianco, Diefes-dux, Mena, & Weller, 2011; Rockland et. al, 2010). Yet, the present study indicated that students either had pre-existing positive attitudes toward engineering and felt that they possessed the necessary traits and skills to succeed in engineering fields, or they had a significant increase in attitudes toward engineering once exposed to an engineering curriculum. In addition, teachers were receptive to the classroom environment and student-centered learning inherent to engineering curriculum. Teachers were able to complete the unit of instruction with minor difficulties in the beginning due to the novelty of the curriculum design and instruction, and were enthusiastic about the changes with regards to their teaching style. While this study had limitations with regards to participants, both teachers and students, and the length of curriculum implementation, the findings suggest the need for further research to better understand the reasons or contextual factors for such a stark contrast between Cambodian students' attitudes and expectations regarding engineering in primary school and their school-to-work and/or university major choices that occur later at the secondary school age, and how exposure to engineering curriculum in schools may promote positive attitudes toward engineering careers.

Conclusion

The integration of a classroom environment conducive to the teaching and learning of engineering has much potential to provide Cambodian students with ample opportunities to harness their potential and succeed in a rapidly evolving 21st Century landscape at the national, regional, and global levels (ASEAN, 2007). The findings in this study are limited since it did not include additional contextual factors pertaining to the Cambodian student attitudes, expectations about school learning. This study explored the impact of an intervention on students' pre-existing ideas about engineering, but was limited in that the study did not account for additional student factors such as academic performance in traditional school settings and student perceptions using qualitative analysis to better understand student perspectives. These variables have been shown to correlate with students' perceived school-to-work transitions, and in the Cambodian context are highly influential on students' career choices (Eng, 2013). These factors may have helped to better explain pre-existing positive attitudes toward engineering, and perhaps school in general. These overall attitudes and beliefs may contribute to students' attitudes toward school that may be related to a more open and positive view of education in general, including content that students have yet to explore.

Further research is needed to explore attitudes and expectations toward engineering and students' self-perceived 21st century skills in more detail. While this study provided baseline results indicating varied levels of student interest and attitudes toward engineering, future studies may investigate a more in-depth understanding of factors influencing these findings. Students at the primary level are at a stage of cognitive development that is highly malleable and influenced by exposure to the world around them. This study indicated that many Cambodian primary students, even without exposure to the highly sophisticated engineering programs and resources seen in developed countries, viewed engineering as a possible career choice in the future. Other Cambodian students that had initially less favorable attitudes and perceptions prior to experiencing the curriculum had significant gains in their attitudes and perceptions of engineering after exposure to the curriculum. These findings indicated significant promise for the adoption of project-based, student centered engineering design activities for Cambodian classroom. Engineering curriculum, as seen in this study, has the potential to provide teaching and learning opportunities conducive to a student-centered, constructivist classroom, that encourages both teachers and students to incorporate new and innovative classroom environments. We contend that it would be beneficial for the Cambodian education system to promote and provide educational opportunities for integrating engineering education at the primary level.

References

Asian Development Bank (ADB) (2015). *Asian Development Outlook 2015: Financing Asia's Future*. Manila, Philippines: Asian Development Bank.

Association of Southeast Asian Nations (ASEAN) (2007). *Cebu Declaration on the Acceleration of the Establishment of an ASEAN Community by 2015*. Retrieved on March 18, 2015, from http://www.asean.org/news

Barron, B. J., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J.D. (1998). Doing with understanding: Lessons from research on problem-and project-based learning. *Journal of the Learning Sciences, 7*, 271-311.

Bielefeldt, A. R., Paterson, K.G., & Swan, C.W. (2010). Measuring the value added from service learning in project-based engineering education. *The International Journal of Engineering Education*, *26*, 535-546.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist*, *26*(3-4), 369-398.

Breunig, M. (2005). Turning experiential education and critical pedagogy theory into praxis. *Journal of Experiential Education, 28*, 106-122.

Brookfield, S. (1996). Experiential pedagogy: Grounding teaching in students' learning. *Journal of Experiential Education, 19,* 62-68.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*, 369-387.

Caleon, I. S., & Subramaniam, R. (2008). Attitudes towards science of intellectually gifted and mainstream upper primary students in Singapore. *Journal of Research in Science Teaching*, *45*, 940-954.

Cantrell, P., Pekcan, G., Itani, A., & Velasquez-Bryant, N. (2006). The effects of engineering modules on student learning in middle school science classrooms. *Journal of Engineering Education, 95*, 301–309.

Capobianco, B. M., Diefes-dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education, 100,* 304-328.

Cejka, E., Rogers, C., & Portsmore, M. (2006). Kindergarten robotics: Using robotics to motivate math, science, and engineering literacy in elementary school. *International Journal of Engineering Education*, *22*, 711.

Christian, M. I. (1999). Reasserting the philosophy of experiential education as a vehicle for change in the 21st century. *The Journal of Experiential Education, 22,* 91-98.

Chu, S. K. W., Tse, S. K., & Chow, K. (2011). Using collaborative teaching and inquiry project based learning to help primary school students develop information literacy and information skills. *Library & Information Science Research, 33*(2), 132-143.

Cunningham, C., & Lachapelle, C. (2010, June). *The impact of Engineering is Elementary on students' attitudes toward engineering and science*. Paper presented at the meeting of American Society for Engineering Education, Louisville, KY.

Dede, C. (2010). Comparing frameworks for 21st Century Skills. In J. Bellanca & R. Brandt (Eds.), *21st Century Skills* (p. 51-76). Bloomington, IN: Solution Tree Press.

Diaz, N. V., & Cox, M.F. (2012). An overview of the literature: Research in P-12 engineering education. *Advances in Engineering Education, 3*, 1-37.

DiFrancesca, D., Lee, C., & McIntyre, E. (2014). Where Is the" E" in STEM for Young Children? Engineering Design Education in an Elementary Teacher Preparation Program. *Issues in Teacher Education*, *23*(1), 49.

Eng, S. (2013). Cambodian early adolescents' academic achievement: The role of social capital. *Journal of Early Adolescence, 33,* 378-403.

Engineering is Elementary (2010). *To get to the other side: Designing bridges.* Boston: Museum of Science.

Estes, C. A. (2004). Promoting student-centered learning in experiential education. *Journal of Experiential Education*, *27*(2), 141-160.

Fallik, O., Eylon, B. S., & Rosenfeld, F. 2008. Motivating teachers to enact free-choice project-based learning in science and technology (PBLSAT): Effects of a professional development model. *Journal of Science Teacher Education*, *19*, 565-591.

Hodson, D., & Hodson, J. (1998). From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science. *School Science Review, 79*, 33-41.

HRINC (2010). *Higher education and skills for the labor market in Cambodia*. Phnom Penh, Cambodia.

Johri, A., & Olds, B.M. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education, 100,* 151-185.

Klein, S. S., & Sherwood, R.D. (2005). Biomedical engineering and cognitive science as the basis for secondary science curriculum development: A three-year study. *School Science and Mathematics, 105,* 384-401.

Krajcik, J. S., & Blumenfeld, P. (2006). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 317-333). New York: Cambridge.

Lachapelle, C. P., & Cunningham, C. M. (2010, June). Assessing elementary students' understanding of engineering and technology concepts. In *ASEE Annual Conference and Exposition, Louisville, KY.*

Linn, R. L. (2003). Accountability: Responsibility and reasonable expectations. *Educational Researcher, 32*, 3-13.

Markham, T. (2011). Project based learning: A bridge just far enough. *Teacher Librarian, 39*, 38.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., & Soloway, E. (1997). Enacting project-based science. *The Elementary School Journal, 97,* 341-358.

Ministry of Education, Youth and Sport [MoEYS]. (2015). *Education strategic plan 2015-2018*. Phnom Penh, Cambodia: Ministry of Education, Youth, and Sport.

Moreno, L., Gonzalez, C., Castilla, I., Gonzalez, E. and J. Sigut. (2007). Applying a constructivist and collaborative methodological approach in engineering education. *Computers & Education, 94*, 891-915.

Myers, A. and J. Berkowicz. (2015). *The STEM Shift: A Guide for School Leaders*. Corwin Press.

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., & Schrader, C. (2009, June). A systemic solution: Elementary teacher preparation in STEM expertise and engineering awareness. Paper presented at the American Society for Engineering Education Conference, Austin, TX.

National Academy of Engineering and National Research Council. (2014). *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. National Academies Press: Washington, DC.

National Research Council (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. National Academies Press: Washington, DC.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.

Palmer, S.R. (1997, January). Engineering education for primary school students. In *Putting students back into engineering education: Proceedings of the 9th annual Convention & Conference, 14-17 December 1997, University of Ballarat, Victoria* (pp. 228-232). School of Engineering, University of Ballarat.

Parry, E. A. (2011). *Making elementary engineering work: Partnerships and practice-North Carolina State University*. Paper presented at the American Society for Engineering Education Conference, Vancouver, BC, Canada.

Partnership for 21st Century Skills (2009). *P21 framework definition*. Washington, DC: Partnership for 21st Century Skills.

Piaget, J. (1952). *The origins of intelligence in children.* New York: International Universities Press.

Reid, J. M. (1987). The learning style preferences of ESL students. *TESOL Quarterly*, *21*(1), 87-111.

Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the “E” in K-12 STEM education. *Journal of Technology Studies, 36*, 53-64.

Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education*, *5*, 17-28.

Sadler, P. M., Coyle, H. P., & Schwartz, M. (2000). Engineering competitions in the middle school classroom: Key elements in developing effective design challenges. *The Journal of the Learning Sciences*, *9*, 299-327.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education*, *94*(1), 87-101.

Smith-Hefner, N. J. (1998). *Khmer American: Identity and moral education in a diasporic community*. Oakland, CA: University of California Press.

Stearns, L. M., Morgan, J., Capraro, M. M., & Capraro, R. M. (2012). A teacher observation instrument for PBL classroom instruction. *Journal of STEM Education: Innovations and Research*, *13*(3), 7.

Szmodis, W. & Eng, S. (2014). The gender dimension in learning achievement and transition to STEM in Cambodia. Bangkok, Thailand: UNESCO.

Thomas, J.W. (2000). *A review of research on project-based learning.* San Rafael, CA: Autodesk Foundation.

United Nations Educational, Scientific and Cultural Organisation [UNESCO]. (2010). *Global monitoring report 2010: Reaching the marginalized*. Retrieved from http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/efareport/reports/2010-marginalization/

United States Agency for International Development [USAID]. (2010). *Review of Cambodia’s science and technology policy and science, technology education and mathematics* (STEM) education policy and practice (Report No. 2). Jakarta.

Vygotsky, L. S. (1967). Play and its role in the mental development of the child. *Soviet Psychology*, *5*, 6-18.

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality*. Princeton, N.J.: The Milken Family Foundation and Educational Testing Service.

Wertsch, J. V. (1997). Vygotsky and the formation of the mind. Cambridge, MA: Harvard University Press.

Woolnough, B. (1993). Teachers' perception of reasons students choose for, or against, science and engineering. *The School Science Review, 75*, 112-117.

Zarske, M. S., Ringer, H. L., Yowell, J. L., Sullivan, J. F., & Quiñones, P. A. (2012). The skyline TEAMS model: A longitudinal look at the impacts of K-12 engineering on perception, preparation and persistence. *Advances in Engineering Education, 3* (2), 1-25.

Appendix A: Pre-test and post-test survey items

EXPECTATIONS ABOUT ENGINEERING ITEMS

How much do you agree with these statements about Engineering?

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
a) Learning about engineering will help me find a high-paying job later on.				
b) Engineering education will help me better prepare for what I want to be when I grow up.				
c) Engineers help make people's lives better.				
d) I will enjoy learning about engineering.				
e) Engineers always cause problems with the things they build and design.				
f) I want to learn about engineering to get a more prestigious job when I grow up.				
g) I would like to learn about engineering because I think it is interesting.				
h) I do not understand why we have to learn about engineering.				

Note: The language used in the above scale resonates within the Cambodian context

ATTITUDES TOWARD ENGINEERING ITEMS

How much do you agree with the following statements about your ideas about Engineering?

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
a) I am good at putting things together.				
b) I like knowing how things work.				
c) I like thinking of new and better ways of doing things.				
d) I would like a job that lets me figure out how things work.				
e) I would like a job where I could invent things.				
f) I would like a job that lets me be creative.				
g) Engineering has nothing to do with real life.				
h) Technology has nothing to do with real life.				
i) I would enjoy a job helping to protect the environment.				
j) I would enjoy a job to make new medicines.				
k) I would like to build and test machines that could help people walk.				
l) I would enjoy being an engineer when I grow up.				
m) I would like to help plan bridges and tall buildings.				

SELF-PERCEIVED 21st CENTURY SKILLS ITEMS

How much do you agree with these statements about yourself?	Agree a lot	Agree a little	Disagree a little	Disagree a lot
a) I work well in groups.				
b) I can think about ideas in new ways.				
c) I communicate my thoughts to others effectively.				
d) I learn a lot from others when I work in groups.				
e) I like to explore new ways of thinking about solutions to problems.				
f) I am a creative person.				
g) Working with other people helps me to think creatively.				
h) I think about what I know in a critical way.				
i) I analyze my understanding of ideas when I learn something new that may challenge those ideas.				
j) I like to talk with others about new ideas.				
k) I would like to work with people who have different ideas than I do.				
l) I am confident in my ability to contribute valuable information to the group I work with.				
m) Working with others is better than working alone.				