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Teacher Beliefs about Motivating and Teaching Students to Carry out Engineering Design Challenges: Some Initial Data

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Keywords

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Abstract

The present study examines middle school teachers' beliefs about seven learning outcomes related to a project that involves developing and examining the effects of a set of engineering design modules constructed for use by middle school math and science teachers. Overall, the teachers involved in the intervention appear to believe they have the instructional skills, professional development, and resources to carry out the modules. Teachers from all of the schools (both intervention and comparison schools) for the most part valued the outcomes as important. Results of the study indicate that, although teachers believe they value and can obtain most of these outcomes; beliefs vary by school and other factors. One area where teachers do not seem strongly efficacious in some schools is that of fostering intrinsic motivation in their students. Teachers in one of the schools where the modules were implemented did not feel their students were capable of becoming intrinsically motivated. The implications for implementing engineering education in middle school of these beliefs and other attitudes are discussed.

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Introduction

There is a great deal of research suggesting that teachers' beliefs about students impacts teachers' success in teaching them (e.g., Archambault, Janosz, and Chouinard, 2012). Just as student attributions are important in determining their success, so too can teacher beliefs about students play a role. Teacher beliefs also have a great deal of impact on the implementation of new curricula. For example, Van Haneghan and Stofflett (1995) studied how teachers' beliefs influenced their implementation of the Adventures of Jasper Woodbury videodisc problem solving series (Cognition and Technology Group at Vanderbilt, 1997). They found that teachers who did not ascribe to the model of learning embodied in the Jasper curriculum did not implement it with as much fidelity as those whose ideas about learning were consistent with that model of learning. Further, the teachers did not value or see the use of the curriculum and were disappointed in it.

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Similar to Jasper, engineering curricula that involve working on design challenges present a similar shift in instruction for teachers. The way that teachers implement engineering design challenges depends on their model of how students learn. Engineering design challenges are student-centered activities where students get opportunities to think creatively, test out models, work collaboratively, and apply mathematics and science. Teachers who are lecture oriented, focused on standardized testing, or who use "canned" science labs have to rethink how they approach instruction to orchestrate design challenges in a meaningful way. Hence, teacher beliefs about whether they have the knowledge, skills, resources, and students to successfully implement design challenges is important to the success of engineering design curricula.

The purpose of the present study was to provide some initial data on teacher beliefs concerning the implementation of engineering design challenges in middle school classrooms. Our project, Engaging Youth in Engineering (EYE), involves designing challenges, implementing them, and eventually seeing their impacts on students. The curriculum was originally designed to involve three design challenges a year during middle school. Generally, we constructed the modules to take around one week to complete, and they involved science and math topics that were consistent with grade level objectives. The modules are unique in that they are not only part of science classes, but also part of mathematics classes. For example, in one module, after creating a wind turbine in science class, students worked with computer simulations of wind turbines in mathematics class. In this class, students solved problems related to the effects of a variety of variables on the amount of electricity generated by a wind turbine. Both science and mathematics teachers are part of the module, and their unique perspectives on the activity are important to capture. The nature of the activities makes them more of a change in practice for mathematics teachers than science teachers. Science teachers have some experience with laboratory activities. Unless mathematics teachers have embraced the use of manipulatives and other constructivist techniques, activities such as those associated with the engineering design modules will be foreign to their teaching approach. We collected the data from this study during the No Child Left Behind era that focused mathematics education back on procedural kinds of activities rather than on conceptual learning. Because of this, we expected some differences in how mathematics and science teachers thought about the modules.

Learning Outcomes

The learning outcomes we chose for the engineering design modules align somewhat with the program outcomes of the Accreditation Board for Engineering and Technology (ABET; ABET, 2009). These outcomes also align with the engineering standards of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). We examined the teacher beliefs about seven general learning outcomes that we propose theoretically should result from the implementation of the modules across the middle school years. Each of these outcomes is consistent with the types of skills that engineers need to be successful. Although these outcomes relate to other areas in addition to engineering, we believe that the engineering design challenges can contribute to learning in these areas. The seven learning outcomes are as follows.

- Students can apply knowledge of mathematics, science, and technology through the engineering design process.
- Students can analyze and interpret data when presented in multiple forms.
- Students can identify, formulate, and solve problems.
- Students know how to communicate effectively.
- Students can function effectively as part of a multidisciplinary team.
- Students are capable of using the techniques, skills, and tools necessary in the modern workforce.
- Students are intrinsically motivated learners who are constantly looking to improve their knowledge.

Although these outcomes are related to the engineering design modules, they are not unlike outcomes that science education reformers have been interested pursuing (e.g., NGSS Lead States, 2013; Rutherford & Ahlgren, 1989).

So theoretically, what kinds of beliefs would be necessary for teachers to effectively help students move toward these outcomes? First, the teachers needed to believe that these outcomes were meaningful. For this reason, we first asked teachers how much they agreed that these outcomes were important for middle school students. The expectancy-value theory of motivation (Wigfield & Eccles, 2000) suggests that teacher motivation to achieve these outcomes might be less if they did not see them as important to student success. Second, we asked the teachers how knowledgeable they were of techniques to obtain these learning outcomes. Theoretically, if teachers believe they have the knowledge and skills to help students obtain the outcomes, they are more likely to succeed in reaching the learning outcomes. Further, as part of our project it was important for us to know whether teachers believed they had the tools to achieve the outcomes or were in need of professional development. For this reason, we also asked teachers how much they agreed that they had adequate professional development to meet the outcomes. Additionally, we asked teachers whether they agreed they had the necessary resources to accomplish these outcomes.

We also asked the teachers about their potential impact on students and the percent of their students they thought were capable of such outcomes. Our question about their ability to impact students focused on teacher efficacy. The question about students' capabilities focused on how teachers viewed their students' abilities to attain the outcomes. From the perspective of models of teacher efficacy or models of teachers' beliefs about student capabilities to learn, we would expect that teachers who felt they could impact students and believed their students capable should be more likely to implement and be successful with the EYE curriculum (Gibson & Dembo, 1984; Tschannen-Moran, Woolfolk-Hoy, & Hoy, 1998; Tschannen-Moran & Woolfolk-Hoy, 2001). Those who do not believe that students are capable and do not believe themselves capable of influencing students should be less likely to be successful. They may not seriously engage in teaching the modules because they do not believe they can make a difference.

Past research on middle school teachers raises this concern even further (e.g., Midgely, Feldlaufer, & Eccles, 1988). Midgely et al. (1988) found that junior high school teachers had less optimism about the ability of their students to learn and a sense that they needed strong behavioral controls more so than upper elementary school teachers of the same cohort of students did. These findings raise concerns about the implementation of the modules, both in terms of the fidelity of implementation and the efficacy of the teachers around some elements of the outcomes the EYE modules are designed to achieve. It also raises an interesting question about whether we can attenuate these beliefs through successful implementation of the modules.

We believe these different teacher beliefs about the EYE outcomes should vary as a function of teacher experience with EYE. Hence, we believe that the schools where EYE has been implemented in its pilot stages should have teachers who value these outcomes more than teachers from schools where it has not been implemented. Further, these teachers should be more knowledgeable, believe they have adequate professional development, and believe that they have adequate resources to meet these outcomes. We also hoped that their efficacy for achieving these outcomes with their students was stronger because theoretically, the success of EYE depends upon successful teacher implementation.

Teacher Efficacy

There is a great deal of research on teacher efficacy (Gibson & Dembo, 1984; Tschannen-Moran, et al., 1998; Tschannen-Moran & Woolfolk-Hoy, 2001), and a significant body of literature on teachers' beliefs about the nature of student abilities, their efficacy to influence student learning, and the impact of those beliefs on student achievement and academic self-concept (e.g., Georgiou, 2008; Kagan, 1990). Most research points out the complexity of determining the impact of teacher beliefs and the large number of component beliefs that influence how teachers teach and students learn. General teaching self-efficacy scales typically have two subcomponents: a personal teaching efficacy that refers to someone's belief in his or her own skills in teaching, and an outcome influence factor that generally gets at whether the teacher believes he or she can have an impact beyond other factors such as home environments, resources, student factors, and so on. One of the debates in the literature on teacher efficacy is the degree to which self-efficacy beliefs need to be contextually bound to predict behavior meaningfully (Pajares, 1996; Tschannen-Moran et al. 1998).

Along with general research on teachers' beliefs, there are also studies of teachers' beliefs about mathematics and science teaching (e.g., Cross, 2009; Enochs & Riggs, 1990; Van Driel, Beijaard, & Verloop, 2001). For example, using the Science Teaching Efficacy Belief Inventory (STEBI, Enochs & Riggs, 1990), Angle and Moseley (2009) found that teachers' outcome expectancies were related to higher levels of proficiency on an end-of-year biology exam. Teachers whose students were proficient had higher outcome expectancy scores than teachers whose students did not succeed. Teachers who believed that learning could occur regardless of other circumstances were more likely to have children who were proficient. Personal teaching efficacy did not make a difference. There is some evidence that teacher expectations of student achievement are strongly linked to actual student achievement in classrooms where high and low achievers are treated differently (McKown & Weinstein, 2008). This suggests that teacher beliefs about student skills influence their treatment of those students. Midgely, Feldlaufer, and Eccles (1989) found that in junior high mathematics courses, student achievement was strongly related to student perceptions of teacher support in the classroom.

Other research on teacher beliefs suggests that teacher beliefs in mathematics and sciences and instructional behaviors are not always consistent. For example, Cross (2009) reports an example of a teacher who thought that more constructivist student-centered strategies were important in geometry, but not in algebra. Van Driel et al. (2001) report that teachers often affirm constructivist and reform beliefs, but tend to still teach in more traditional ways. The EYE module implementation depends upon the teachers using student-centered reform based practices to implement the modules. The degree to which they affirm those beliefs and put more constructivist-based teaching practices into practice is expected to influence the success of the modules in impacting students.

Because engineering education in the K-12 environment is relatively new (Honey, Pearson, & Schweingruber, 2014), there are few studies of teachers' beliefs about engineering education. Honey et al. (2014) report literature that focuses largely on the lack of teacher efficacy related to their lack of content knowledge. However, most of what they review refers to hypothetical teaching rather than their efficacy after having had professional development related to engineering content. There is the beginning of a literature on teacher beliefs about engineering specifically. Yasar, Baker, Robinson-Kurpius, Krause, and Roberts (2006) developed a questionnaire that explored general beliefs and interest of K-12 teachers concerning engineering education. Yasar et al. (2006) explored four different sets of beliefs about engineering education: (a) the importance of engineering education, (b) familiarity with engineering education, (c) stereotypical characteristics of engineers, and (d) characteristics of engineering. Essentially, they found that teachers valued engineering education, were not very familiar with it, leaned toward some stereotypic beliefs, and generally knew characteristics of engineering. Although the present authors have some concerns over the nature of some of the scales, it can nevertheless be reasonably inferred that teachers value engineering education, but do not know much about it. Unlike Yasar et al.'s (2006) more general approach, the present investigation examines more specific beliefs about learning outcomes that an actual engineering middle school curriculum is attempting to inculcate in two schools.

Phelps, Nathan, Atwood, Prevost, and Tran (2009) developed the Engineering Education Beliefs and Expectations Instrument (EEBEI). Their instrument had seven scales, and they examined changes in high school teachers' views after attending a summer institute and teaching an introductory engineering education class. They found that after these professional development and teaching experiences, teachers reported more connections to engineering in their content course teaching, higher perceived resource support, and greater sensitivity to tailoring instruction to students' academic performance. Their study indicates that professional development related to engineering education may have a positive impact on teachers and students.

Overall, the literature points to the importance of beliefs to educational practice. It also points to the importance of seeing how beliefs are connected to practice when involved in innovations that involve student centered teaching. Finally, in general, teachers do not know much about engineering education, but as Phelps et al. (2009) show, engineering education professional development can have a positive impact on teachers' knowledge and beliefs.

Research Questions

Based on our project goals and the literature, we developed two research questions. First, what are the beliefs of teachers in EYE schools concerning the learning outcomes as the EYE modules are developed and fully implemented? Second, how do the beliefs of the EYE teachers compare to those in matched comparison schools? Both of these questions were formative in that they provided us with information that could help us determine the potential success of EYE and target professional development for our EYE teachers.

Methodology

Participating Teachers

The present study looked at the beliefs of 43 math, science, and technology teachers from four different middle schools. Two of the schools were part of the EYE project and two were comparison schools. The curriculum developers, in collaboration with the school district, approached middle schools that would be most likely to feed in to a high school with a pre-engineering curriculum. Of the three schools initially approached, principals at two of the schools agreed to participate in the program. Of the two implementing schools, one is a math/science magnet school and the other is a regular middle school. In the participating schools, all math and science teachers participated in EYE as part of their regular teaching responsibilities. EYE was not an optional activity. The two comparison schools were chosen based on their being the best matches to the participating schools possible as far as achievement, SES status, and ethnic makeup. Of the two comparison schools, one is a magnet school focusing on the humanities, and the other was a regular middle school.

During the two years prior to the present study, EYE teachers had several types of professional development, including orientation workshops, curriculum development time, mini-unit implementation, instructional technology, and content workshops. Initial professional development occurred during the curriculum development phase of the project, and utilized modules that were still in development. EYE teachers also attended ASEE +K12 workshops and had an EYE coach. Stipends were always provided and principals provided substitute teachers. In addition, volunteers supported teachers as they implemented the units.

The teachers in the EYE schools had taught a median of 12 years, and the comparison schools teachers had taught a median of 10 years. Among the EYE teachers (24 of 25 reporting), there were 14 who were mathematics teachers (3 of whom also taught technology related courses), 12 taught science (2 also taught mathematics and technology, and 1 taught a technology course), and 4 taught technology courses (all whom taught either mathematics, science, or both). Among the comparison schools teachers (18 out 18 reporting) 8 reported teaching science, 9 reported teaching mathematics, 1 reported teaching a technology course (and also taught mathematics), and 1 teacher reported teaching mathematics and science. Teachers were about equally divided through the middle school grade levels (6–8), although the magnet schools also had fifth grade teachers. Although the initial analyses consider both the magnet and regular middle schools, we focused later analyses on the regular middle school teachers, who were from schools that were better matched than the magnets.

Instrumentation and Procedure

As part of baseline data collection during the fall of 2009, we gave the teachers a questionnaire to assess their beliefs about themselves and their students. The teachers' responded to statements that reflected the seven EYE learning outcomes. These outcomes were consistent with the 21st Century Learning Standards. The outcomes also partially match up with the ABET Standards (ABET, 2009) and the NGSS (NGSS Lead States, 2013). Hence, they are expectations that have face validity and are consistent with descriptions of skills needed to be successful in 21st century occupations (see Table 2 [later in paper] for a list of the outcomes).

For each of the seven learning outcomes, the questionnaire asked teachers to rate how much they agreed that: 1) the outcome was important for middle school students, 2) that they had knowledge of the instructional techniques necessary to obtain the outcome, 3) they had professional development opportunities to help them accomplish the outcomes, and 4) whether they had the necessary resources to obtain the outcome. These items were rated on a Likert-type scale with responses ranging from 1 (Strongly disagree) to 5 (Strongly agree). For each of the seven outcomes, teachers were asked whether they had the ability to teach their student these skills (rated on a five point scale with 1 indicating no ability and 5 indicating exceptional ability), and what percentage of their students (in 10% increments) could obtain these skills. These data were the first efforts at assessing the beliefs of this group of teachers. We have planned a follow-up survey to study the changes in the beliefs of these teachers as we reach the end of the project.

We examined both the individual items and scales developed using summated ratings across the seven outcomes for each item stem. The overall scales had reasonable internal consistency (Cronbach alphas ranged from 0.83 to 0.94). The survey was distributed online through Survey Monkey, and a drawing for a gift card was used as an incentive for teachers to respond. Return rates for the two EYE schools were very high (school 1–81% of the teachers, school 2–89% of the teachers). The return rates were somewhat lower in the comparison schools, but over half still responded (72% and 56%).

Results

Data Analysis Overview

Given that the study addresses a new area of curriculum with very little evidence, we were not stringent in controlling for Type I error in our analyses. At this stage of the research process, we are interesting in exploring the data for potential effects. Our sample size is not large, so that our power is somewhat limited. We would rather risk Type I errors than Type II errors at this stage of the research process and depend upon replication or the failure of replication to ultimately determine the impact of the program on teachers.

Overall Differences

As noted above, to gain an overall sense of differences in teacher beliefs, six scales were created reflecting the average ratings across the seven learning outcomes. Further, as noted above, the scales had reasonable Cronbach alphas ranging from 0.83 to 0.94 indicating there was some coherence in the responses teachers made. Independent *t*-tests were conducted to examine differences between the EYE schools and the comparison schools on the scales created for each item stem. Table 1 below illustrates means and standard deviations for the schools on the six different scales.

Independent *t*-tests found differences in three of the six areas. These were the areas that we would expect to see differences for teachers who had some training on using the modules. Teachers from EYE schools indicated that they had more knowledge of instructional techniques that could reach the outcomes ($t(36) = 2.81$, $p < 0.009$, Cohen's $d = 0.93$), professional development to meet the outcomes ($t(36) = 4.06$, $p < 0.001$, Cohen's $d = 1.35$), and resources to meet the outcomes ($t(36) = 4.29$, $p < 0.001$, Cohen's $d = 1.42$). These are not surprising given these teachers had begun implementation of EYE.

There were no differences in valuing the overall EYE outcomes, the ability of the teachers to impact the EYE outcomes, or in how much the teachers valued the outcomes. Generally, both groups show moderately high levels of value for EYE outcomes, moderate levels of belief that they can achieve the outcomes, and believe that about 70% of their students can achieve the outcomes overall (the mean is 6.86, but each unit increase means 10% more students).

The analyses carried out above compared the regular and magnet EYE schools' teachers to the regular and magnet comparison schools' teachers. For two reasons, we decided to focus further analyses only on the regular middle schools. One reason is that the regular schools were better matched on academic achievement and curriculum emphasis. The magnet schools each had a different curriculum emphasis (one centered on the arts and the other centered on math and science). These schools were more likely to draw students and teachers whose interests and aptitudes

Table 1
Means and standard deviations for the six scales based on the six item stems in EYE and comparison schools.

Item stem	School	N	M (SD)
Teacher efficacy	EYE	23	3.40 (0.86)
	Comparison	16	3.12 (0.70)
Value outcomes	EYE	25	3.82 (0.76)
	Comparison	15	3.58 (0.74)
Knowledgeable	EYE	23	3.86 (0.62)
	Comparison	15	3.30 (0.55)
Professional development	EYE	23	3.85 (0.53)
	Comparison	15	3.00 (0.77)
Resources	EYE	23	3.68 (0.66)
	Comparison	15	2.74 (0.66)
Students capable	EYE	24	6.86 (2.46)
	Comparison	16	6.89 (1.81)

were consistent with the schools' curricular emphasis. Further, because teachers knew that students needed to go through a selection process to enroll at the magnet school, they might have viewed these students differently than they viewed regular school students. It is difficult to parse out any impact this might have. A second reason is that our initial examination of the data indicated that teachers at the EYE magnet school had more positive attitudes overall about their own and their students' efficacy than did teachers at the regular EYE school. Given that the EYE magnet school is a math/science magnet school, it would be unsurprising for teachers at this school to feel that they and their students are more efficacious for these outcomes. For these reasons, we focused additional analyses on the regular schools.

In particular, we were interested in how the teachers in these two regular middle schools viewed their students because past literature (Midgely et al., 1988, 1989) suggests that middle school teachers did not see middle school students as competent learners who could handle complex learning tasks. Because we excluded the magnet school teachers for this analysis, there were a smaller number of participants in each group. We examined the differences between the teachers in the two regular middle schools on the seven EYE learning outcomes. We were interested in whether they believed their students could acquire the EYE competencies. Thus, we looked at the item for each competency that asked them what percentage of students could acquire the respective EYE competency. Because of the distribution of the data on these measures, we decided to dichotomize the outcomes. We examined what percent of students teachers thought could achieve each of the learning outcomes. Specifically, we compared the number of teachers at regular (non-magnet) schools who believed 50% or less of their students could achieve the outcome and the number who believed more than 50% of their students could achieve the outcome.

Fisher's exact test was used to examine differences between groups because of the small sample size. The Fisher's exact test allows testing of the exact probability of rejecting the null hypothesis based on a binomial distribution when the cell counts are too small to perform a Chi-square (Siegel, 1956).

Table 2 shows the percentages and identifies statistically significant differences. There were significant differences on three of the seven outcomes. Less than half of the EYE regular school teachers reported that they believed that more than 50% of their students could analyze interpret data, identify formulate, and solve problems, and become self-directed learners. We are particularly concerned that nearly three quarters of EYE teachers at the regular school believe that 50% or fewer of their students were capable of becoming self-directed learners. These results are of concern, even if were to just view them descriptively. That teachers who were engaged in a new curriculum did not think that many of their students could achieve the competencies that were part of that program suggests the need for further investigation.

To gain more insight into the potential reasons for their beliefs, we examined whether teachers' efficacy in teaching to these outcomes was related to their beliefs about their students' abilities to master them. Given the small N, it was not possible to address this question by school, but instead, we looked at the correlation between the teachers' beliefs about their own efficacy in developing these competencies and the teachers' beliefs about their students' abilities to master these competencies.

We computed Pearson correlation coefficients to assess the relationship between teacher efficacy for each learning outcome and the percent of students teachers thought were

Table 2
Percent of teachers who believe their students can achieve outcome by school.

Outcome	School	50% or fewer can achieve	More than 50% can achieve
Apply knowledge of mathematics, science and technology through the engineering design process	EYE Regular	53.3%	46.7%
	Comparison Regular	58.3%	41.7%
Analyze and interpret data when presented in multiple representations***	EYE Regular	53.3%	46.7%
	Comparison Regular	8.3%	91.7%
Identify, formulate and solve problems**	EYE Regular	60.0%	40.0%
	Comparison Regular	16.7%	83.3%
Communicate effectively	EYE Regular	46.7%	53.3%
	Comparison Regular	25.0%	75.0%
Function as part of a multidisciplinary team	EYE Regular	40.0%	60.0%
	Comparison Regular	33.3%	66.7%
Use the techniques, skills and tools necessary in the modern workforce	EYE Regular	66.7%	33.3%
	Comparison Regular	50.0%	50.0%
Motivated learners who recognize the need for, and engage in, ongoing learning*	EYE Regular	73.3%	26.7%
	Comparison Regular	33.3%	66.7%

*$p = 0.057$
**$p = 0.05$
***$p = 0.019$

capable of achieving the outcome for the regular middle school teachers. As can be seen in Table 3 below, for all outcomes, we found a positive correlation between teacher efficacy and the percent of students teachers thought were capable of achieving each of the learning outcomes. These results suggest, unsurprisingly, that there is a moderate relationship between teacher and student efficacy, and that teacher efficacy appears to be a reasonable candidate for explaining the differences between the teachers in the EYE and comparison school. A larger study with a greater N would be necessary to build a stronger case, but these data suggest a consistent relation between teacher efficacy and student ability to acquire these skills.

One descriptive comment by a teacher in the EYE school may provide some insight into why teachers felt that they were less efficacious. The teacher indicated that he or she could not compete with other elements of culture to motivate students. Hence, there were concerns over the ability of these teachers to motivate students. If EYE is to meet its goal of helping students become self-directed learners, then there is a need for these teachers to believe they can impact their students or they will not be likely to put much effort into motivating students.

Discussion

The overall results from this study suggest that early on in the development and implementation of the program, the EYE schools showed some differences in their sense of preparedness to meet the EYE outcomes. The overall results show differences in favor of EYE for items related to professional development, knowledge of instructional techniques, and resources available to meet the goals. Similar to Phelps et al. (2009), we found that teachers with some initial experience in working with engineering education seemed to score higher. Additionally, there were no differences between the EYE and comparison schools on the valuing of the learning outcomes; teachers at both schools seemed to value the learning outcomes.

In response to our research question comparing EYE teachers to comparison school teachers, we do find that the EYE teachers have a greater sense of efficacy in some aspects of EYE. Although, as we note in the results, their sense of efficacy is sometimes lower than one would expect based on beliefs that they have had adequate professional development to encourage the EYE competencies we note in this paper. There are patterns in the data, however, that could be cause for concern or that could indicate areas for professional development within regular EYE middle schools. First, we did find that there was room for growth in most areas. This is not surprising given that the project was at an early stage when we collected these data. Second, teachers in the regular EYE school did not have as strong a belief in their students' abilities to acquire some of the EYE competencies as teachers in the regular comparison school. Over half of the teachers did not believe that the majority of their students could develop competencies in analyzing and interpreting data; identifying, formulating, and solving problems; and becoming self-directed learners. This is in spite of reporting that they had adequate professional development to teach these skills, and their reporting of higher levels of preparation than the comparison school teachers. Further, this is in spite of standardized tests indicating similar average levels of achievement in both regular middle schools.

Interpreting data and solving problems are areas that reflect competencies in students that can be easily identified within curriculum areas, so developing efficacy in these areas can be clearly be connected with curriculum. One way to address these issues would be by providing experiences for teachers and students. The lack of teacher efficacy in these areas can be resolved to some extent by improving content knowledge and providing professional development in pedagogical strategies. To some extent, this is consistent with the conclusions of Honey et al. (2014) about the importance of improving teacher content knowledge. The EYE teachers received some professional development in engineering content and pedagogical strategies early in the project. As the project has progressed, teachers have continued to receive professional development in these areas. This additional professional development may have an impact on teacher efficacy.

Teacher beliefs that their students their students could become self-directed learners are more difficult to change.

Table 3
Pearson coefficients for teacher self-efficacy and % of students capable of achieving an outcome.

Outcome	% of students capable of achieving outcome
Apply knowledge of mathematics, science and technology through the engineering design process	0.51*
Analyze and interpret data when presented in multiple representations	0.48*
Identify, formulate and solve problems	0.69***
Communicate effectively	0.57**
Function as part of a multidisciplinary team	0.64***
Use the techniques, skills and tools necessary in the modern workforce	0.55**
Motivated learners who recognize the need for, and engage in, ongoing learning	0.46*

*$p < 0.05$
**$p < 0.01$
***$p < 0.001$

Prior research (Midgely et al., 1988, 1989) suggests that teachers' beliefs that middle school students cannot self-regulate are pervasive in middle schools. Although there has not been a recent replication of Midgely et al.'s (1988, 1989) work, the test and procedural focused instruction facilitated by No Child Left Behind would be likely to foster such beliefs rather than attenuate them. Although one could provide professional development related to pedagogical strategies that would impact self-directedness, one would also have to change the attitudes of the teachers concerning the efficacy of such strategies.

In summarizing their "How People Learn" model, Bransford, Brown, and Cocking (1999) note that the ability to become a life-long learner is a key component to students succeeding in the 21st century. Education policy makers very commonly talk about changing jobs and careers, dealing with new technologies, and adjusting to the rapid change. For this reason, there is great concern when teachers do not seem to think that students can become self-directed.

These data point to an important consideration for programs that wish to engage students in engineering design challenges. Clearly, teacher beliefs about student motivation need to be addressed. If teachers believe that they cannot help build more internal motivation in their students, then it will be important to address these beliefs and provide teachers with strategies when implementing engineering design challenges. As Landis (1995) points out, the engineering profession depends on self-directed learners. Discussions of 21st century learning outcomes also focus strongly on internal motivation to learn. Not only do teacher beliefs need to be addressed, but engineering design curricula need to incorporate ways to change student motivation. To some extent, the design process is inherently motivating, but scaffolds for increasing motivation appear to be needed to be sure that processes that enhance motivation take place. Glazewski and Ertmer (2010) point out the importance of this issue in addressing problem and project-based learning activities. They suggest that teachers need more professional development and more strategies for improving their students' performance in problem and project-based activities such as engineering design modules.

Returning to teacher efficacy, the findings here indicate that overall EYE teachers seem to believe that for the most part they have the knowledge and the skills to implement the EYE modules. They have, for the most part, personal teaching efficacy (Gibson & Dembo, 1984; Tschannen-Moran & Woolfolk-Hoy, 2001) with regard to the modules. However, at least at one EYE school, they do not have this personal teaching efficacy for building intrinsic motivation in their students. This is concerning, because teacher expectations are predictors of student cognitive engagement and achievement in math (Archambault et al., 2012). Additionally, if the students recognize that their teachers' hold such negative beliefs about their abilities to self-regulate, it is likely to have a negative impact on student motivation and achievement (Archambault et al., 2012; Midgely et al., 1989).

Some teachers in the EYE school also appear to think that their students do not have the capacity to reach the outcome of becoming a self-directed learner. Because of this, it is unclear that their outcome efficacy is very high in this area as well. As noted earlier, beliefs about the inability of students to make positive academic progress seem to be much stronger among junior high teachers than among elementary school teachers (Midgely et al., 1988). This may indicate a culture of negative stereotypes about young adolescents that perpetuate teacher behaviors that counteract programmatic efforts. Students are aware of the change in teacher attitudes toward and treatment of them from elementary to middle school. The student belief that teachers are not as supportive in junior high has a negative impact on the students' perceptions of the usefulness and importance of math (Midgely et al., 1989). For low performing students, this early negative impact on performance may make future improvements difficult as they progress through junior high and into high school (Archambault et al., 2012).

Teacher efficacy and beliefs are important to any innovation in education. Teachers' beliefs about students, curriculum, and effective instructional strategies can lead to either success or failure of an initiative and changing teacher beliefs and practices is a difficult process (Van Driel et al., 2001). Hence, tracking, examining, and influencing what teachers believe about outcomes related to engineering education is an important activity for researchers to continue to study. Additionally, researchers should pay close attention to a school's cultural attitudes about student ability to achieve challenging outcomes. Otherwise, the integration of engineering education into the K-12 sector will run into the same difficulties as other reform efforts.

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