Epistemological Beliefs of Engineering Students

Bethany A. King and Susan Magun-Jackson

Abstract

This study examined undergraduate and graduate engineering students' epistemological beliefs as a function of their educational level. Schommer's (1998) Epistemological Questionnaire was used to assess the beliefs in quick learning, certain knowledge, fixed ability, and simple knowledge of 396 students attending two universities in Western Tennessee. Additional analyses examined the effects of background characteristics, such as gender, ethnicity, and high school grade point average. Results indicated that freshmen and sophomores were more likely than juniors and seniors to have beliefs in quick learning and certain knowledge above and beyond the effects of the background characteristics. There were no significant differences in graduate students' and undergraduate students' beliefs. The results of this study also indicate that engineering students' beliefs are related to their advancement in problem-solving processes in an undergraduate engineering curriculum.

Keywords: college students, engineering education, epistemological beliefs

Epistemological Beliefs of Engineering Students

For the past years, there have been reports that address the concern that the United States is globally losing its competitive edge in the fields of Science, Technology, Engineering, and Mathematics (STEM) (Committee on Science, Engineering, and Public Policy [COSEPUP], 2007). The United States' competitive edge in STEM fields is important to maintain because science and technology perpetuate growth in the economy and contribute to national security. Furthermore, there is a concern that as American science and engineering workers approach retirement, the number of scientists and engineers to replace them will constantly decline (COSEPUP, 2007). As a result, the engineering community has started a reform in engineering education (National Academy of Engineering [NAE], 2005). A primary step in implementing this reform is to understand what constitutes the nature of engineering knowledge ("The Research Agenda," 2006).

What is Epistemology?

Epistemology is a branch of "philosophy concerned with the nature and justification of human knowledge" (Hofer & Pintrich, 1997, p. 88). First influenced by the genetic epistemology research of Jean Piaget, educational psychologists study epistemological development and beliefs to determine how students come to know what beliefs they have about knowledge and how epistemological beliefs affect cognitive processes (Hofer & Pintrich, 1997). For example, William G. Perry, Jr. is credited for being the first educational psychologist to study the educational experiences of college students (Perry, 1970). Since then, Perry's research has served as a framework for epistemological development studies (Culver & Hackos, 1982; Fedler & Brent, 2004; Hofer & Pintrich, 1997; Schommer, 1990).

Perry's Model

Perry is considered by many as the pioneer of epistemological development studies of college students (Hofer & Pintrich, 1997; Muis, 2004). Using open-ended questions, Perry (1970, 1988) conducted two longitudinal studies in which he interviewed male college students about their perceptions of what influenced their college experience. He noticed changes in the students' thinking processes (Perry, 1970), and these changes occurred in patterns as they progressed through college (Perry, 1988). Using these patterns, Perry (1988) mapped the students' college experiences and developed the foundation of his epistemological development theory. His theory consisted of four broad classifications that represent the students' overall views: in dualism, knowledge was based on one right answer from an authority figure, in multiplicity, knowledge was based on differing opinions, in relativism, knowledge was dependent on a given scenario, and in commitment, knowledge was a decision based on known information. Research studies have shown that most engineering undergraduates complete college in the lower classifications of either dualism or multiplicity (Culver & Hackos, 1982; Felder & Brent, 2004; Fitch & Culver, 1984; Marra & Palmer, 2004; Pavelich & Moore, 1996).

Compared to other epistemological theories, Perry's theory has been the one most applied to engineering education (Fedler & Brent, 2005).

Schommer's Model

Being the first to develop a quantitative measure of epistemological beliefs, Schommer's (1990) research was different from other epistemological beliefs models in that she suggested that epistemological beliefs were not unidimensional, but multidimensional and independent (Schommer 1990, 1993, 1997; Schommer & Walker,1995). She suggested that the epistemological beliefs system consisted of five dimensions; however, as her research continued, only four dimensions consistently appeared in factor analysis results. These four dimensions each had a dichotomous relationship of either a naïve belief or a sophisticated belief. The dimensions were structure of knowledge (knowledge was either simple and consisted of isolated pieces of information or complex and consisted of interdependent pieces of information), certainty of knowledge (knowledge was either absolute and not changing or continuously evolving), control of knowledge (knowledge was fixed or incrementally increased and improved), and speed of knowledge (knowledge was quickly obtained or perceived as a gradual process) (Hofer & Pintrich, 1997; Schommer 1993, 1997; Schommer & Walker, 1995). Although not used as often as Perry's (1970) framework, Schommer's (1990) questionnaire has served as a framework for several epistemological studies that evaluated engineering students (Jehng, Johnson, & Anderson, 1993; Paulsen & Wells, 1998; Schommer, 1990; Schommer, 1993; Trautwein & Ludtke, 2007).

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Perry framework. In 1996, Pavelich and Moore used Perry's epistemological development model to rate undergraduate engineering students on their perceptions of knowledge and found significant differences in the ratings between freshmen and seniors, between freshmen and sophomores, and between sophomores and seniors. In another study, Wise and colleagues (2004) found that educational level also had a significant effect on engineering students' Perry ratings; there were significant differences between students' freshman and senior years and between their junior and senior years. Although Marra, Palmer, and Litzinger (2000) did not consider educational level, their study examined the effects of a first-year design course on engineering students' epistemological beliefs. They found that students who took the course had significantly higher Perry ratings, which were above and beyond the effects of math and verbal SAT scores and GPA, than students who had not taken the course. In addition, Marra and Palmer (2004) found that engineering students' Perry ratings were correlated with the use of engineering design principles in solving ill-structured problems. Students who were skilled in solving ill-structured problems were more likely to have higher Perry ratings than students who were not skilled in solving ill-structured problems. In this same vein, Palmer and Marra's (2004) study found that engineering students who were exposed to open-ended problem solving within a science domain were more likely to have higher Perry ratings in epistemological beliefs related to the science domain than their Perry ratings in the beliefs related to the humanities/social sciences domain.

Schommer Framework. After the initial and trailblazing development of the Schommer Epistemological Questionnaire (SEQ) (Schommer, 1990), Schommer (1993) conducted a study with community college students and university students and found that community college students were more likely to believe that knowledge was simple, certain, and quick, whereas university students were more likely to believe that knowledge was innate. In another study, Jehng, Johnson, and Anderson (1993) conducted a cross-sectional investigation and found that graduate students were less likely than undergraduate students to have beliefs in certain and simple knowledge. In addition, upper level undergraduate students were less likely than lower level undergraduate students to have certainty beliefs. Jehng and colleagues (1993) also found that engineering students were the most likely of students in all fields to believe that knowledge was certain. In a similar study, Paulsen and Wells (1998) found that students' epistemological beliefs became more sophisticated as they progressed in their levels of education. Also, engineering students were more likely than those students in humanities/arts, social sciences, and education to believe that knowledge was certain, simple, and acquired quickly beyond the effects of age, gender, education level, and GPA. In a study that only examined certainty beliefs, Trautwein and Ludtke (2007) found that engineering students were more likely to have naïve certainty beliefs than students in other academic majors (e.g., humanities/arts, mathematics/natural sciences, business, social sciences, medicine, and law). In addition, engineering students were the only group to show an increase, although slight, in their certainty scores during the period of the study.

Statement of the Problem

Epistemological beliefs of college students have been examined by both qualitative and quantitative research methods. Studies that have used both of these methods provide support that epistemological beliefs become more sophisticated as students' educational level advances (Jehng, et al., 1993; Paulsen & Wells, 1998; Pavelich & Moore, 1996; Schommer, 1993; Wise et al., 2004). Although qualitative research methods have been used to solely examine engineering students, a gap in the literature exists in that quantitative studies have not been conducted to solely examine the relationship between epistemological beliefs (in each of the four dimensions) and educational level of engineering students. Hence, the purpose of this study is to use Schommer's Epistemological Questionnaire (Schommer, 1990, 1998) to measure engineering students' epistemological beliefs at five educational levels and to answer the primary research questions: Do epistemological belief dimensions (certainty, structure, control, and speed) of engineering students significantly differ across educational levels (freshman, sophomore, junior, senior, and graduate)? If the beliefs significantly differ by educational level, do these differences still exist when background variables are controlled?

Method

Participants

A total of 396 undergraduate and graduate engineering students from two universities in Western Tennessee voluntarily participated in this study during the fall semester of 2008. Students were surveyed in 25 classes within the engineering disciplines of civil, biomedical, chemical, electrical, engineering management, and mechanical.

Materials

Schommer Epistemological Questionnaire. The Schommer Epistemological Questionnaire (Schommer, 1990, 1998) was used to assess the students' epistemological beliefs within four dimensions: certainty of knowledge (e.g., knowledge was either absolute and not changing or continuously evolving); structure of knowledge (e.g., knowledge was either simple and consisted of isolated pieces of information or complex and consisted of interdependent pieces of information); control of knowledge ability (e.g., knowledge was fixed or incrementally increased and improved); and speed of knowledge (e.g., knowledge was quickly obtained or perceived as a gradual process). Participants were presented 63 statements about knowledge and learning, and they were asked to rate the statements, such as "The only thing that is certain is uncertainty itself," using a Likert scale which ranged from 1 = strongly disagree to 5 = strongly agree.

Background information form. The students were surveyed to determine their personal and pre-college characteristics using Barker's (1998) background information form. As a result, the students' self-reported their gender, ethnicity, high school grade point average, educational level, and engineering discipline.

Procedure

Engineering students were recruited from two Western Tennessee universities to voluntarily participate in the study. They were told that the objective of the study was to gather data on engineering students' beliefs and views toward various topics. Participants were given the epistemological questionnaire and background information questionnaire during their regularly scheduled class time.

Participants were divided into three groups according to their classification (lowerclassmen: freshmen and sophomores; upperclassmen: juniors and seniors; graduate: master and doctoral). High school grade point average was divided into three groups (below average, average, and above average), and ethnicity was divided into three groups (European American, African American, and Other ethnicity). Subsequently, dummy-coded variables were created whereas lowerclassmen, European American, and above average were the primary reference groups for their respective measurements.

Results

After reviewing the returned surveys for errors, 370 surveys were included in the analyses. There were 304 students who identified themselves as males and 62 students identified themselves as females. In addition, 182 students identified themselves as lowerclassmen and 167 students identified themselves as upperclassmen. The majority of the students reported that they were European American (68%). The remainder of the students reported their ethnicity as African American (15%), Asian American (6%), Hispanic (2%), Multi-ethnic/racial (2%), Native American (1%), and Other (6%). Students' major fields of study consisted of seven categories: civil, mechanical, electrical, biomedical, chemical, engineering management, and other.

The first research question, "Do engineering students' epistemological beliefs in each dimension (e.g., fixed ability, simple knowledge, quick learning, and certain knowledge) significantly differ across educational levels (e.g., freshman, sophomore, junior, senior, and graduate)?" was answered by using one-way analysis of variance (ANOVA). Two of the four epistemological belief factors were found to be significantly different across the educational levels at the $p < .05$ level: quick learning F (2, 301) = 3.06, $p < .05$, $\eta_p^2 = .02$ and certain knowledge F (2, 301) = 3.95, $p < .05$, $\eta_p^2 = .02$.

Since the test of homogeneity of variances for beliefs in quick learning was violated, the Robust Tests of Equality of Means was also evaluated. Based on the Welch test, the belief in quick learning for the three educational levels closely approached statistical significance at the $p < .05$ level: F (2, 49.208) = 3.07, $p = .056$. Beliefs in fixed ability and simple knowledge did not vary across educational levels.

Post hoc pair-wise comparisons that were based on Tukey's HSD tests for unequal samples were used to identify the specific pairs of educational level groups that differed significantly in quick learning and certain knowledge beliefs. However, the variances for the belief in quick learning were not equal; therefore, the Games-Howell test was also used to identify the specific pairs of educational level groups that differed significantly in quick learning beliefs. Lowerclassmen were significantly more likely to have naïve beliefs in quick learning than did upperclassmen ($p < .05$). Moreover, lowerclassmen were significantly more likely to have naïve beliefs in certain knowledge than did upperclassmen ($p < .05$).

The second question, "Do these differences still exist when background characteristics (i.e., gender, ethnicity, high school grade point average) are controlled?" was answered using hierarchical regression analyses to examine the relationships between each epistemological belief factor and educational level while controlling for the influence of the background measures of gender, high school grade point average (GPA), and ethnicity. Since gender was the only dichotomous variable, dummy-coding was used for the remaining three variables: educational level, high school GPA, and ethnicity. Two groups of educational level (i.e., upperclassmen graduate) were included in the analysis; the largest group (lowerclassmen) was used as the primary reference group. In addition, two groups of high school GPA (i.e., above average and below average) were included in the analysis, and average was used as the primary reference group. Moreover, two groups of ethnicity (i.e., African American, Other ethnicity) were included in the analysis, and the largest group, European American was the primary reference group.

The five background variables (i.e., gender, above average GPA, below average GPA, African American, and Other ethnicity) were entered at Step 1 into each equation prior to the educational level variables (i.e., upperclassmen, graduate) that were entered at Step 2. F-tests for each regression showed that the R^2 was significant for the beliefs in fixed ability and quick learning.

Step 1 explained 5.2% of the variance in the belief in fixed ability. After entry of the upperclassmen and graduate students at Step 2, the total variance explained by the model as a whole was 5.4%, F (7, 280) = 2.28, $p < .05$. The two control measures explained an additional .02% of the variance in fixed ability, after controlling for gender, above average GPA, below average GPA, African American, and Other ethnicity, R squared change = .002, F change (2, 280) = .25, $p = .779$. In the final model, neither upperclassmen nor graduates were statistically significant predictors offixed ability (see Table 1 for details).

Step 1 explained 8.4% of the variance in the belief in quick learning. After entry of the upperclassmen and graduate students at Step 2, the total variance explained by the model as a whole was 10.5%, F (7, 280) = 4.69, $p < .001$. The two control measures explained the additional 2.1% of the variance in quick learning, after controlling for gender, above average GPA, below average GPA, African American, and Other ethnicity, R squared change = .021, F change (2, 280) = 3.32, $p < .05$. In the final model, upperclassmen, as compared to the lowerclassmen reference group, was the only educational level that was statistically significant (beta = -.150, $p < .01$). These results suggest that upperclassmen, which are the same gender, have the same high school GPA, and are the same ethnicity, are less likely to have naïve beliefs in quick learning than the reference group lowerclassmen (see Table 1 for details).

Step 1 explained 1.2% of the variance in the belief in certain knowledge. After entry of the upperclassmen and graduate students at Step 2, the total variance explained by the model as a whole was 3.7%, F (7, 280) = 1.55. However, this model as a whole was not statistically significant. The two control measures explained 2.6% of the variance in certain knowledge, after controlling for gender, above average GPA, below average GPA, African American, and Other ethnicity, R squared change = .026, F change (2, 280) = 3.76, $p < .05$. In the final model, upperclassmen, as compared to the lowerclassmen reference group, was the only educational level that was statistically significant (beta = -.138, $p < .05$). Although the overall model was not significant, these results suggest that upperclassmen, which are of the same gender, have the same high school GPA, and are the same ethnicity, are less likely to have naïve beliefs in certain knowledge than the reference group lowerclassmen (see Table 1 for details).

Results for the background variables indicate that females were less likely than males to have naïve beliefs in fixed ability (beta = -.203, $p < .05$) and quick learning (beta = -.274, $p < .05$). Students with above average high school GPA's were more likely to have naïve beliefs in fixed ability than students with average high school GPA's (beta = .129, $p < .05$). Finally, African American students were more likely to have naïve beliefs in simple knowledge than did European Americans (beta = .151, $p < .05$).

Discussion

The results of this study suggest that there are some differences in engineering students' epistemological belief dimensions across educational levels. In fact, three conclusions about engineering students can be tentatively drawn. First, upperclassmen are less likely than lowerclassmen to have beliefs in two dimensions: quick learning and certain knowledge. Second, educational level still predicts beliefs in quick learning and certain knowledge when background characteristics of students are the same. Third, epistemological beliefs differ according to gender, high school GPA, and ethnicity. In the following sections, each of these conclusions will be discussed further.

Conclusions

Upperclassmen vs. Lowerclassmen. This study supports several epistemological studies in that there are findings that college students' beliefs become more sophisticated as they progress through school (Jehng, et al., 1993; Paulsen & Wells, 1998; Pavelich & Moore, 1996; Schommer, 1993; Wise et al., 2004). However, this study's findings are only present for engineering students' beliefs in quick learning and certain knowledge. More specifically,

Table 1 Hierarchical Multiple Regression Analyses for Variables Predicting Engineering Students' Epistemological Beliefs in Fixed Ability, Quick Learning, Certain Knowledge, and Simple Knowledge.

	Fixed		Quick		Certain		Simple	
Predictor	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	.052**		.084***		.012		.022	
Control variables[a]								
Step 2	.002		.021*		.026*		.003	
Upper classmen		-.04		-.150*		-.138*		.02
Graduate		.005		-.04		.06		.05
Total R^2	.054*		.105***		.037		.025	
n	304		304		304		304	

Note. Reference group for high school GPA is average GPA, the reference group for ethnicity is European American, and the reference group for educational level is Lower classmen.
[a]Control variables included above average GPA, below average GPA, gender, African American, and other ethnicity.
*$p < .05$. **$p < .01$. ***$p < .001$.

the beliefs became more sophisticated as students progressed from lowerclassmen (i.e., freshmen and sophomores) to upperclassmen (i.e., juniors and seniors). Like these authors, Jehng and colleagues (1993) found support that upperclassmen are less likely to have beliefs in certain knowledge. This is more than likely because upperclassmen have had exposure to ill-structured problem solving in design courses; therefore, they have learned that knowledge changes and is not absolute (Marra & Palmer, 2004; Marra et al., 2000).

Although other studies (Paulsen & Wells, 1998; Schommer, 1993) found that engineering students are more likely than other majors to have naïve beliefs in quick learning and certain knowledge, it is noteworthy that these studies are similar to the current study in that they found the students' beliefs in these dimensions became more sophisticated in their junior and senior years. Ironically, this progression in students' knowledge (from naïve to sophisticated thinking) is in line with the engineering education reform to increase students' engineering knowledge and prepare them for professional practice (Accreditation Board for Engineering & Technology, 2007; NAE, 2005; "The Research Agenda," 2006).

Based on the epistemological beliefs literature, it was expected that this study would have supported differences between undergraduate and graduate engineering students' beliefs. However, this study found no differences in beliefs between undergraduate and graduate students. This finding is similar to Jehng and colleagues' (1993) finding that graduate students did not differ from undergraduate students in their beliefs in fixed ability and quick learning. In contrast, Jehng and colleagues (1993) did find that graduate students were less likely to have beliefs in simple knowledge and certain knowledge.

Educational level predicts beliefs regardless of background characteristics. Students enter college with various backgrounds and experiences; therefore, it is important to consider these characteristics as confounding variables when evaluating educational outcomes. It was interesting to find that upperclassmen were less likely than the lowerclassmen to have beliefs in quick learning and certain knowledge above and beyond the effects of gender, high school GPA and ethnicity. Other studies of college students (Marra et al., 2000; Paulsen & Wells, 1998; Schommer, 1993) also found epistemological belief differences remained over and beyond the effects of background characteristics. For example, Marra et al. (2000) found that a change in the engineering curriculum affected epistemological beliefs of students over a period of four years regardless of their background characteristics. In another study, Paulsen and Wells (1998) found that engineering students were more likely than other majors to have beliefs in simple knowledge, quick learning, and certain knowledge when gender, GPA, and educational level were the same. However, Schommer (1993) found that lowerclassmen engineering students' beliefs in quick learning disappeared when background characteristics were controlled. With all of this in mind, one cannot assume that background variables will not ever influence the epistemological beliefs of engineering students.

Background characteristics predict beliefs. Not only did this study find that educational level predicts engineering students' beliefs beyond background characteristics, but the background characteristics also predict the students' epistemological beliefs. For example, females were less likely than the males to have beliefs in fixed ability (beta = -.203, $p < .05$) and quick learning (beta = -.274, $p < .05$). Although Paulsen and Wells (1998) and Schommer (1993) did not limit their studies to engineering students, they also found that college females were less likely than college males to have beliefs in quick learning and fixed ability.

An additional finding in this study is that engineering students with above average high school GPAs were more likely to have beliefs in fixed ability as compared to engineering students with average high school GPAs. In contrast, Schommer (1993)found that the less likely high school students, although not identified as future engineering students, believed in fixed ability, the more likely they were to have higher high school GPAs. Furthermore, Marra and colleagues (2000) did not find a relationship between high school GPA and first-year engineering students' epistemological beliefs.

Finally, the finding that being African American, as compared to being European American, is more likely to predict beliefs in simple knowledge was unexpected. This is because significant results for ethnicity have not been reported in any other epistemological beliefs studies. Consequently, Hofer and Pintrich's (1997) review expressed a need for studies that examine epistemological beliefs across cultures and ethnic groups. This research would also be useful in the field of engineering education in that there is a need in the United States to attract more minorities to study engineering.

Limitations and Future Research

As with all studies, the current study is not perfect and has its limitations. These limitations include generalizability, low reliability, and small effect sizes. For example, the generalizability of this study is only applicable to engineering students with similar characteristics and to students in Western Tennessee universities.

The lack of differences between graduate and undergraduate students beliefs can be attributed to the small and limited sample of graduate students (n = 19). It is reasonable to believe that the expected differences between graduate and undergraduate students might have been realized if the sample of graduate students was larger. More research is needed that examines epistemological belief differences between graduate and undergraduate engineering students in order to understand how curriculum and the classroom environment influence or correlate with their academic achievement and behavior in terms of epistemological beliefs.

Ethnicity was also a limitation that affects the generalizability of this study. The largest ethnic groups in this study were European American and African American, respectively. The other groups were less than half the size of both groups. As a result, one cannot assume that the findings of this study would be consistent cross-culturally. In agreement with Hofer and Pintrich (1997), there is a need to study epistemological beliefs among cultures and ethnicities because most epistemological beliefs studies are conducted with white males. In the same vein, there is a need for more epistemological beliefs research that studies engineering students of different cultures and ethnicities.

The low reliability values, which ranged from -.084 to .521, and small effect sizes for this study can be explained by Wood and Kardash's (2002) findings that the design of an epistemological beliefs study may affect reliability values and effect sizes. For example, they found studies that evaluated samples with wide ranges were more likely to have higher internal consistencies than studies with samples that had narrow ranges. This study's sample had a narrow range in that it only assessed students in one field of study (e.g., engineering). Wood and Kardash (2002) also warned researchers that low reliability should not prevent them from identifying differences between groups. As a probable solution to improve reliability, Wood and Kardash (2002) suggested that researchers increase items that represent a construct of a measure. Their rationale for this solution was that the reasoning and vocabulary of epistemological research was complex, and more items must be loaded on a participant's score. Furthermore, Hofer and Pintrich (1997) mentioned that Schommer's (1990) questionnaire has construct validity issues in content. As a result, Hofer and Pintrich (1997) believed there was a possibility that Schommer's (1990) questionnaire would not have accurate indicators of beliefs about knowledge and would have high construct-irrelevant variance.

Finally, SAT scores and high school GPA were self-reported by the students; therefore, it is reasonable to question the accuracy of this data. Some students could not remember this information and left the items blank on their answer sheets. As a result, their data was eliminated from some of the data analyses. In addition, some students probably guessed their scores and GPA. Guessing would also result in inaccurate findings in the study. In future research, it would be preferable to obtain examination scores and GPA data directly from the records office of the university.

Implications

Currently, there are many initiatives underway to increase student enrollment in the fields of science, technology, engineering, and mathematics (STEM). Engineering education researchers are contributing to these initiatives by focusing their research on five major areas; one area of interest is engineering epistemologies. Hence, engineering education researchers are investigating what constitutes the nature of engineering knowledge and ways of engineering thinking ("The Research Agenda," 2006). This study contributes to the engineering epistemologies research in that its findings support the idea that the epistemological beliefs (i.e., certain knowledge, quick learning) of engineering students become more sophisticated as the students advance in their undergraduate engineering curriculum.

These findings are important to engineering education because they can be used to identify the specific parts of the curriculum that influence sophisticated, or advanced, cognitive processes (e.g., engineering thinking) in engineering students. For example, engineering education researchers could examine the curricula and classroom environments to identify whether they correlate to the differences in the epistemological beliefs between lowerclassmen (i.e., freshmen, sophomores) and upperclassmen (i.e., juniors, seniors). However, that type of investigation would not provide a complete context for acquiring engineering knowledge as it would only identify external influences on engineering students' cognitive processes.

In order to develop an effective engineering curriculum that supports the overall development of sophisticated engineering thinking, engineering education researchers might also identify internal influences on cognitive processes as they relate to the changes in the students' epistemological beliefs. Understanding students' internal influences is important, because they might work in conjunction with the external influences (e.g., teacher, peers, curriculum, classroom environment) to facilitate learning and the acquisition of engineering knowledge.

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