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Epistemological Beliefs of Electrical Engineering: A Case Study*

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This study investigates electrical engineering students' engineering epistemological beliefs by using the Chinese version of the Epistemological Beliefs Assessment for Engineering (CEBAE). We recruited 468 electrical engineering students from two research-based universities in Taiwan. Prior to the study, confirmatory factor analysis and reliability testing involving 188 engineering students were performed to evaluate the validity and reliability of the CEBAE. The results revealed that Taiwanese engineering students in research-based universities had only slightly sophisticated engineering epistemological beliefs. Students' educational backgrounds influenced their engineering epistemological beliefs. As the grade level progressed, students' engineering epistemological beliefs became more sophisticated (with the exception of the third year). Female engineering students exhibited significantly more sophisticated engineering epistemological beliefs compared with their male counterparts.

Keywords: engineering epistemology; electrical engineering education; engineering philosophy

1. Introduction

An epistemological belief is defined as personal understanding regarding the nature of knowledge and knowing. Research on students' epistemological beliefs is based on epistemological analysis in the field of educational psychology [1]. Educational pioneers Perry and Schommer investigated the effects of college students' epistemological beliefs on their cognitive learning process [2]. According to Perry's epistemological theory, college students' epistemological beliefs may be grouped into four stages: dualism, multiplicity, relativism and commitment [3]. In contrast to Perry's epistemological developmental model, Schommer developed a quantitative measurement consisting of four dimensions for assessing college students' epistemological beliefs: structure of knowledge, certainty of knowledge, control of knowledge, and speed of knowledge [2]. Engineering education researchers have frequently employed these two frameworks recently to interpret students' epistemological beliefs [4].

Engineering epistemology is application research that only focuses on the constituents of the nature of engineering thinking and knowledge. It is also considered one of five future research themes in engineering education [5] and one of anticipated abilities for future engineers [6]. From a pedagogical perspective, the engineering epistemology approach enables educators to examine the status of college students' philosophical views on engineering thinking [1, 4] and to investigate the effects of students' epistemological beliefs on their engineering design [7]. However, according to a recent content analysis study [8], of the journal articles published in major engineering educational journals, only a few concerned engineering epistemology research. Students' engineering epistemological beliefs have not received substantial attention in engineering education. Therefore, additional research on students' engineering epistemological beliefs should be conducted for filling this gap [9–11].

Two representative studies on engineering students' traditional epistemological beliefs were noted in the literature. Based on Perry's developmental model, Marra and Palmer [12] divided engineering students into two groups: those with high and low levels of epistemological beliefs. Furthermore, they interviewed the students regarding their educational experiences. Their results revealed that both groups had similar views on teaching, learning, and group work, but different perspectives on problem- solving and the entire college experience. King and Magun-Jackson [4] employed Schommer's epistemology questionnaire for measuring engineering students' epistemological beliefs, and reported that different dimensions in students' epistemological beliefs differed significantly across educational levels, and were correlated to engineering learning experiences. However, although these two studies had reported the educational values of epistemology, their con-

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cepts were based on general educational viewpoints rather than engineering epistemological beliefs.

Because of the unique culture of engineering education [13], a new measurement tool, the Epistemological Beliefs Assessment for Engineering (EBAE), was used in this study to examine students' engineering epistemological beliefs. The EBAE combines epistemological components, similar to those in Perry and Schommer's works, with engineering philosophy, and was developed specifically for engineering students [14]. Applying the EBAE in classrooms might enable researchers to obtain the status of students' engineering epistemological beliefs immediately. This study was conducted as exploratory research for which a Chinese version of the EBAE was devised, after which 468 students' engineering epistemological beliefs were analyzed. The implementation of this study is anticipated to provide an alternative research design for understanding students' engineering epistemological beliefs, but also offer a knowledge foundation on the development of Asia—Pacific electrical engineering education. Specifically, the study addresses two primary research questions:

1. What is the current status of Taiwanese students' engineering epistemological beliefs in research-based universities?
2. What was the effect of Taiwanese students' background information (gender and grade) on their engineering epistemological beliefs?

2. Engineering epistemology

Hofer and Pintrich [1] reviewed the most common theories of epistemological beliefs, and indicated that two research dimensions might represent core structures in these theories: nature of knowledge and nature of knowing. The nature of knowledge dimension contains two subcategories: certainty of knowledge and simplicity of knowledge. By contrast, the nature of knowing dimension contains two subcategories: source of knowledge and justification for knowing. In each subcategory, a dichotomous continuum from the left to the right position interprets students' philosophical standpoints. For example, moving toward the right position in the continuum represents students' more sophisticated thinking in one specific subcategory. Table 1 lists in summary form the interpretation for the continuum proposed by Hofer and Pintrich [1].

Based on Hofer and Pintrich's [1] epistemological interpretation model, Carberry et al. [14] incorporated engineering thinking into the core structures of epistemological beliefs, and developed the EBAE measurement for quantifying students' engineering epistemological beliefs. The original core structures were categorized into certainty of engineering knowledge, simplicity of engineering knowledge, source of engineering knowledge, and justification of engineering knowing. Table 2 lists the definition of each structure in the EBAE.

Carberry et al. [14] used the EBAE to measure first-year college students' engineering epistemological beliefs, and reported that the lowest score was observed in certainty of engineering knowledge, whereas the highest score was noted for simplicity of engineering knowledge. Slightly sophisticated patterns were observed in source of engineering knowledge and justification of engineering knowing. Students' overall engineering epistemological beliefs are situated at the center. However, because of the new manner in which the EBAE is being used in the literature, no subsequent studies have adopted the measurement to validate the quantitative data obtained by Carberry et al. Thus, the

Table 1. Interpretation for the Continuum by Hofer and Pintrich

Toward Left Continuum	Core Structure	Toward Right Continuum
Absolutism	1. Certainty of knowledge	Relativism
Concrete	2. Simplicity of knowledge	Contextual
External authority	3. Source of knowledge	Self as knower
Dualism	4. Justification for knowing	Multiplicity

Table 2. Core Structure of the EBAE by Carberry et al

Core Structure	Definition
1. Certainty of engineering knowledge	Is engineering knowledge fixed (absolutism) or fluid (relativism)?
2. Simplicity of engineering knowledge	Is engineering knowledge an accumulation of discrete facts (concrete) or highly interrelated concepts (contextual)?
3. Source of engineering knowledge	Is engineering knowledge fixed natural ability residing in experts (external authority) or can most people have the ability to construct engineering knowledge (self as knower)?
4. Justification of engineering knowing	Does engineering learning just passively accept or absorb information (dualism) or actively evaluate information by multi-sources (multiplicity)

Table 3. Survey Design in the Study

Structure	Items	Question Design	Literature Support
Part one (Background)	2	Gender: 1. Male 2. Female Grade: 1. First Year, 2. Second Year, 3. Third Year and 4. Forth Year	Paulsen and Wells [15] and King and Magun-Jackson [4]
Part two (Epistemology)	13	5-point Liker-type: 1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Strongly agree	Caberry et al. [14]

Table 4. Results of Factor Analysis (n = 188)

Item	Factor 1	Factor 2	Factor 3	Factor 4
1-1	0.68			
1-2	0.82			
1-3	0.76			
2-1		0.77		
2-2		0.73		
2-3		0.79		
3-1			0.64	
3-2			0.76	
3-3			0.61	
3-4			0.62	
4-1				0.62
4-2				0.73
4-3				0.65
Eigen-vale	1.71	1.34	1.21	1.72
% of Variance	56.9	45.94	73.78	69.05

% of Variance for Total is 58.

influence of other factors such as gender and grade on students' engineering epistemological beliefs remains unknown.

3. Research methods

3.1 Research design

This study adopted the quantitative-based survey methodology for data collection. College students' engineering epistemological beliefs were dependent variables as well as the primary focus of the study. Students' educational backgrounds (gender and grade) were independent variables, and were considered factors potentially influencing their engineering epistemological beliefs. The survey design contained 15 question items. The research design in the survey structure was supported by a theoretical discussion in the literature. Table 3 shows the survey design used in the study.

3.2 Research instrument

This study employed the EBAE by Carberry et al. [14] to assess students' engineering epistemological beliefs. The EBAE uses a 13-item 5-point Likert scale, and contains four psychological constructs: certainty of engineering knowledge, simplicity of engineering knowledge, source of engineering knowledge, and justification of engineering knowing. Overall scores ranged from 13 to 65. Higher scores in the EBAE represent more sophisticated beliefs for engineering. Carberry et al. [14] reported that two rounds of factor analysis involving more than 400 students validated the survey items.

The Chinese version of the EBAE (CEBAE) was constructed using three major stages. First, one professor of English literature and one professor of engineering education independently translated the EBAE into a Chinese questionnaire. Second, an initial CEBAE was administered to 10 engineering students to ensure item accuracy. Finally, the subsequent modified CEBAE was validated through a confirmatory factor analysis and a reliability testing from a sample of 188 engineering students. Table 4 and Table 5 list the results of confirmatory factor analysis and reliability testing. Overall, the loading of each item and the reliability coefficient for each survey construct were both higher than 0.6, indicating excellent reliability and validity of the CEBAE [16, 17].

3.3 Research participants

We used the convenience sampling principle [18], and included electrical engineering students from

Table 5. Results of the Reliability Test (n = 188)

Survey Construct	Question Items	Reliability Coefficient	Correlation Coefficient (with total scores)
1. Certainty of engineering knowledge	3	0.73	0.72**
2. Simplicity of engineering knowledge	3	0.63	0.64**
3. Source of engineering knowledge	4	0.84	0.77**
4. Justification of engineering knowing	3	0.81	0.75**
Total	13	0.75	1

$^{**}P < 0.01$.

Table 6. Profiles of the Research Participants (n = 468)

Type	Number
1. Gender*	
A. Male	392
B. Female	76
2. Grade**	
A. First Year	110
B. Second Year	116
C. Third Year	127
D. Forth Year	115

* Women in electrical engineering are minority.
** Students in each grade level are approximately equal.

two research-based universities in Taiwan. These two universities are located in Northern and Southern Taiwan, respectively. According to a recent report on the academic ranking of world universities, the field of electrical engineering at these two schools was ranked in the top 50 category [19]. Based on the statistical report released by the Ministry of Education in Taiwan [20], the total number of electrical engineering students at all research-based universities in Taiwan was approximately to 5,000.

During a one-month research campaign, 10 electrical engineering professors from the two universities participated in this study. Professors administered the CEBAE to students during their regular teaching sessions. Student participants competed the survey within 15 min in the classroom. In total, 468 copies of valid questionnaires were collected. Lodico et al. [21] indicated that if the number of participants in a study is approximately 5,000, the sample size of participants should number at least 350. Therefore, the number of research participants in this study fulfilled the sampling requirement. Table 6 lists in summary form the profiles of the research participants.

3.4 Data analysis

We used descriptive and inferential statistics to report the quantitative data. The analytical results for descriptive statistics were interpreted using the mean and standard deviation for each survey construct. In inferential statistics, one-way multivariate analysis of variance (MANOVA) and the Kruskal-Wallis (KW) test were conducted to investigate the effects of gender and grade on students' epistemological beliefs. The rationale for using the KW test was that the number of male and female students was unequal.

Table 7. Mean Scores for Survey Constructs (n = 468)

Survey Construct	Mean	S.D.
1. Certainty of engineering knowledge	2.94	0.76
2. Simplicity of engineering knowledge	3.86	0.60
3. Source of engineering knowledge	3.07	0.42
4. Justification of engineering knowing	3.04	0.51
Total	3.22	0.37

4. Results

4.1 Overall status of engineering epistemological Beliefs

The results of descriptive statistics regarding students' epistemological beliefs are listed in Tables 7–9. Overall, the findings revealed that students' engineering epistemological beliefs were slightly sophisticated (M = 3.22). The highest score was obtained for simplicity of engineering knowledge (M = 3.86), whereas the lowest score was obtained for certainty of engineering knowledge (M = 2.94). In addition, slightly sophisticated beliefs were observed in source of engineering knowledge (M = 3.07) and justification of engineering knowing (M = 3.04).

Overall, an analysis across grade levels revealed that senior college students (M = 3.29) had more sophisticated beliefs compared with freshmen (M = 3.23), sophomore (M = 3.26), and junior (M=3.15) students. From the first year to second year, students' engineering epistemological beliefs increased with the grade level. However, regardless of the four survey constructs, the lowest scores were observed for the third-year students. When the grade level increased to the fourth year, students' epistemological beliefs in the four constructs rebounded. Regarding gender analysis, female students' epistemological beliefs (M = 3.32) were more sophisticated than those of male students (M = 3.21). The same pattern was observed in the four survey constructs.

4.2 Effects of gender and grade

The MANOVA results for the grade level and KW test for gender are listed in summary form in Tables 10 and 11, respectively. Regarding the effect of the student grade level, significant differences were

Table 8. Mean Scores for Survey Constructs by Grade (n = 468)

Survey Construct	First (S.D.)	Second (S.D.)	Third (S.D.)	Forth (S.D.)
1. Certainty	2.81 (0.83)	2.96 (0.72)	2.84 (0.80)	3.18 (0.64)
2. Simplicity	3.90 (0.50)	3.93 (0.49)	3.80 (0.58)	3.81 (0.54)
3. Source	3.08 (0.58)	3.10 (0.46)	3.01 (0.56)	3.08 (0.46)
4. Justification	3.07 (0.54)	3.09 (0.54)	2.95 (0.54)	3.08 (0.52)
Total	3.23 (0.47)	3.26 (0.37)	3.15 (0.46)	3.29 (0.34)

Table 9. Mean Scores for Survey Constructs by Gender (n = 468)

Survey Construct	Male (S.D.)	Female (S.D.)
1. Certainty	2.92 (0.76)	3.08 (0.77)
2. Simplicity	3.83 (0.61)	3.99 (0.53)
3. Source	3.06 (0.42)	3.08 (0.43)
4. Justification	3.02 (0.51)	3.14 (0.56)
Total	3.21 (0.37)	3.32 (0.36)

observed in certainty of engineering knowledge (F = 5.87, $p < 0.01$) and total CEBAE (F = 13.34, $p < 0.05$). Post hoc analysis revealed significant differences between senior and junior students in engineering knowledge, and between senior and freshmen students in total CEBAE. Regarding the effect of the students' gender, significant differences were observed in simplicity of engineering knowledge ($\chi^2 = 4.42, p < 0.05$), justification of engineering knowing ($\chi^2 = 3.74, p < 0.05$) and total CEBAE ($\chi^2 = 7.42, p < 0.01$). Post hoc analysis revealed that female students' epistemological beliefs were significantly higher than those of male students in simplicity of engineering knowledge, justification of engineering knowing, and total CEBAE.

5. Discussion

From an engineering training perspective, company employers expect hired college graduates (or future engineers) to demonstrate highly sophisticated engineering epistemological beliefs [12, 22], which are directly relevant to the engineering design of technology products [7]. However, in the study, the descriptive statistics indicated that Taiwanese students had only slightly sophisticated engineering epistemological beliefs. Although the overall score moved toward a positive side on the continuum, a wide gap persisted between practical circumstances in schools and the ideal status in the workplace [11]. Future discussions on whether the current engineering education curriculum in Taiwan yielded such findings are warranted.

Regarding performances in each construct, a polarized result was obtained in the survey. The lowest score was observed in certainty of engineering knowledge, whereas the highest score was obtained in simplicity of engineering knowledge. The scoring pattern was similar to that observed

Table 11. Kruskal-Wallis Test Results by Gender

Survey Construct	χ^2	DF	*P*	Post Hoc
1. Certainty	3.29	1	0.07	
2. Simplicity	4.42	1	0.04*	Female > Male
3. Source	0.34	1	0.56	
4. Justification	3.74	1	0.05*	Female > Male
Total	7.42	1	0.00**	Female > Male

*$p < 0.05$, ** $p < 0.01$.

in the study by Carberry et al. [13], in which only engineering freshmen students were included as participants. In addition, the findings revealed that electrical engineering students perceived engineering knowledge as fixed (absolutism) and interrelated concepts (contextual). This phenomenon can be attributed to a complex knowledge system in electrical engineering and obedience culture in Taiwanese engineering students [23], who believe that engineering principles from textbooks are fixed [13].

In theory, when students progress through school, their epistemological beliefs may become more sophisticated [1, 2]. In teaching practice, Wise et al. [24] reported a similar pattern after investigating engineering undergraduates' traditional epistemological beliefs (Perry's model). However, in this study, students' engineering epistemological beliefs became more sophisticated as they progressed to the second and fourth year. In the third year, their engineering epistemological beliefs in each survey construct suddenly decreased. One possible explanation may be that junior engineering students in Taiwan began taking more advanced engineering courses (e.g., capstone courses), rather than learning basic engineering knowledge. These courses potentially caused a sense of discomfort in them. Although being familiar with complex engineering designs, students' engineering epistemological beliefs rebounded significantly in the fourth year.

The study by Belenky et al. [25] on women's ways of knowing articulated the different thinking model for female students. In empirical studies, Chou and Chen [26] and Chou [27] have also reported that women in engineering often displayed different cognitive thinking processes and learning patterns when adjusting in engineering learning systems. In

Table 10. MANOVA Results by Grade

Survey Construct	SS	DF	MS	F	*P*	Post Hoc
1. Certainty	9.96	3	3.32	5.87	0.00**	D>A* , D>C*
2. Simplicity	5.84	3	1.95	6.97	0.26	
3. Source	7.87	3	2.62	9.73	0.31	
4. Justification	6.22	3	2.07	7.17	0.08	
Total	6.79	3	2.26	13.34	0.02*	D>C*

*$p < 0.05$ ** $p < 0.01$. A: First B: Second C: Third D: Forth.

this study, female students' engineering epistemological beliefs yielded results similar to those reported in the literature. Overall, female engineering students exhibited significantly more sophisticated engineering epistemological beliefs compared with their counterparts. Specifically, female engineering students' engineering epistemological beliefs outperformed those of male students significantly in simplicity of engineering knowledge and justification of engineering knowing. In other words, compared with their counterparts, female engineering students perceived engineering as a more complex learning system, but they might be willing to construct engineering knowledge actively.

Because of the limitations in the research design, the results of this study cannot be generalized into other engineering students from different cultural backgrounds. However, certain research strategies can be proposed for prompting the development regarding future studies in engineering epistemology. First, engineering students' academic performances in the study, particularly for women in engineering, were not obtained. Additional studies comparing students' engineering epistemological beliefs with their academic performances should be conducted. Second, only electrical engineering students were included in this study. Future studies may extend the sample scope by recruiting similar educational background students, such as those studying computer engineering or electronic engineering. Finally, capstone courses had a potential influence on students' engineering epistemological beliefs in the study. Additional studies examining the causal relationship between engineering curriculum design and students' engineering epistemological beliefs are warranted.

6. Conclusion

This purpose of the study was to examine electrical engineering students' engineering epistemological beliefs by using a validated measurement. Through statistical analysis, it was observed that the current status of Taiwanese engineering students' engineering epistemological beliefs in research-based universities was slightly sophisticated. In addition, students' educational backgrounds exerted a strong effect on their engineering epistemological beliefs. Typically, students' engineering epistemological beliefs became more sophisticated when the grade level progressed. Female engineering students' engineering epistemological beliefs outperformed those of male students significantly. However, because of unique design of a case study, engineering educators who were interested in college students' engineering epistemological beliefs should be wary of the findings when discussing implications regarding teaching practice.

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