AC 2011-1533: HOW DO THEY THINK? ENGINEERING COLLEGE STUDENTS' CONCEPTIONS OF ELECTRICITY

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Abstract

The present study was a follow-up research[1] in which we had found that Electro-Magnetics was considered as the most difficult domain for the engineering college students in physics studies. The purpose of this study was focus on exploring the engineering college students ' conceptions of electricity. It should be noticed that university of technology (UT) in Taiwan is categorized to vocational education system. Therefore, in physics learning, the performance of UT student should be something different from general university (GU) student. We adopted the Electricity Conception Test (ECT) developed by Bilal and Frol[2] as the instrument to understand the engineering college students' conceptions of electricity. The total participants were 461 freshmen that were selected from 3 UT in Taiwan. The participants were categorized as three groups (high-, H-UT; mid-, M-UT; low-, L-UT) by the scores in the integrated entrance examination of UT. Furthermore, in order to understand the difference between GU students and UT students in the physics learning. Another 99 engineering college students from a mid-level GU were selected. After data analysis, some interesting research findings were discussed and will be suggested to the practice of physics curriculum design in university of technology.

Background and Purpose

To cope with demands of the 21[st] century, people need higher-level thinking skills such as self-directional and problem-solving skill[3]. And student should be equipped with properly proficiency for a productive adult life. For example, all students should be educated to be "STEM-capable"[4]. Recently, physics instruction and achievement are increasingly important for today's society as evidence by the Physics First and Physics for All movement[5]. In other words, physics education is viewed as important for developing scientific literacy and necessary for all people[6].

The implication of teaching physics is not primarily the gaining of knowledge, but rather the intensive instruction in cognitive abilities. However, even after years of science instruction, most students (including those considered good students) do not provide evidence of meaningful concept learning[7]. Many science teachers did not realize that students hold their naïve idea about the world to come to learn science in the school. In addition, the role of students' pre-instructional conceptions that are not in accordance with scientific concepts has proven to be important in science learning[2].

Many studies had verified that students and adults are accustomed to solve problems in physics on the basis of everyday concepts[7]. Those individual's conceptions differed from scientific knowledge were often called different term, but the one most common and appealing one is 'alternative conceptions'[8]. It is helpful for science educator to explore students' alternative conceptions. Electricity is one of the basic scientific topics with relevance to every life. To date, there are many studies had been carried out to determine students' understanding on electrical conceptions[1, 2, 8, 9, 10]. It is found that as students progress through their science curriculum over the years, many students form a working mental model of electrostatic and magnetic interactions based on observations in classroom demonstrations or experimental explorations or everyday play[9]. Besides, most students, even university students, have ontological and epistemological difficulties using the idea of the electric field, thus preferring the use of reasoning based on the Newtonian model of action at a distance to solve problems [10]. These studies had shown that the alternative conceptions of electricity can be seen in all age groups, students, teachers and adults [2]. That is also the main focus we concerned in this study.

Recently, one of the most salient trends in education is the steady increase in attainment. But we can not assume that higher levels of educational attainment and investment automatically result in greater learning[11]. To date, most of senior high school graduated students go to college or university in Taiwan. However, we should pay more attention about students' learning in higher education system. Generally, physics is one of the subjects that students feel it is difficult to learn for every grade level student in Taiwan. It should be noticed again, university of technology in Taiwan is categorized to vocational education system. Therefore, the performance of UT students in physics learning should be something different from GU students.

Based on our previous study[1] we had found that Electro-Magnetics was considered as the most difficult domain for the engineering college students in physics studies. In order to enhance the science learning achievement of UT students in Taiwan, it is crucial to understand the engineering college students' conceptions of electricity. In sum, the purpose of this study was focus on exploring the engineering college students' conceptions of electricity.

Method and Design

Based on the pre-study of the reality of physics curriculum/learning in the universities of technology in Taiwan[1], we have found that Electro-Magnetics was considered as the most difficult domain for the engineering college students. So the purpose of the second-year study was focus on exploring the engineering college students' conceptions of electricity.

In the present study, we adopted the Electricity Conception Test (ECT) developed by Bilal and Frol[2] as the instrument to understand the engineering college students' conceptions of electricity. The ECT consisting of eight sub-topics and including 23 two-tier conceptual questions was translated into Chinese. The researcher translated the English version of ECT into Chinese and then it was back-translated by a bilingual professional translator. In the present study, the α value of ECT were higher than 0.78, implying that a good internal consistency existed. Besides, an expert panel of two science educators and two doctoral students in science education were asked to evaluate the validity of ECT. In addition, the Chinese translation of ECT was confirmed by interviewing three grade two general university students. The panel members' and students' feedback was collected and then used to refine the Chinese translation of ECT.

The total participants were 461 freshmen that were selected from 3 UT in Taiwan. In order to explore the performances of different level UT students, the participants were categorized as three groups (high-, H-UT; mid-, M-UT; low-, L-UT) by the scores in the integrated entrance examination of UT. There were 141 students in group H-UT, 142 students in group M-UT and 178 students in group L-UT. Furthermore, in order to understand the different performances between GU students and UT students in the physics learning. Another 99 engineering college students from a mid-level general university were selected.

In order to collect the stable state of UT students in physics learning, the research instrument were sent to the sampled schools in the end of semester. In other words, these students had previously been taught the topics of this research. To analysis the data in this study, answering percentages of the choices for every question and the statistical methods, analysis of variance [ANOVA], were conducted. ANOVA is a kind of statistical methods for comparing means of several groups. In addition, we used a four-item criterion to assess students' explanations in ECT. The criterion consisted of Correct Explanation (CE), Wrong Explanation (WE), Uncodable Explanation (UE), and No Explanation (NE).

Result

There were eight sub-topics in ECT including: (1) Electrical force, (2) Motion in an electric field, (3) Conductors and insulator in an electric field, (4) Charge transfer, (5) Work between equipotential lines, (6) Charging and discharging in a DC circuit, (7) Current in a DC circuit, and (8) Charging and discharging of a capacitor. ECT was designed as two tier question. In the first tier, the participants were asked to recognize the proper answer. In the second tier, they were asked to write down their reasons and evidences for their choices. In the following tables, the correct choices were given in bold face.

The performance of UT student in ECT

Table 1 presented the percentages of choices and explanations for sub-topic 1 concerning the conception of electrical force. The question one and two were designed to explore students' ideas about the forces between two charged particles.

Table 1. Percentages of the choices and explanations for the questions 1 and 2.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
1	UT	12.4	28.4	**54.2**	4.1	0.7	25.6	18.4	7.6	48.4
	GU	1.0	8.1	**90.9**	0.0	0.0	77.8	13.1	0.0	9.1
2	UT	16.1	**55.2**	23.7	4.3	0.7	20.7	17.1	7.8	54.2
	GU	6.1	**84.8**	8.1	1.0	0.0	70.7	16.2	2.0	11.1

As shown in table 1, most of UT and GU students were aware of that two charged particles exert equal force on each other. However, some UT students indeed hold alternative conceptions. There was about 28 percent of UT students thought that the body having a larger charge would get a bigger force. In addition, there was about 24 percent of UT students also thought that two particles having equal force exerting on each other would move with the same speed no matter what their masses are. In other words, the UT student preferred to use of reasoning based on the Newtonian model of action at a distance to solve problems [10]. The Newtonian model of action supposes that the force between two objects is related to the masses and distance of two particles. It should be noticed that the UT students did not provide explanations to support their choices. On the other hand, most of GU students could recognize the scientific conceptions and provide explanations to support their choices.

Table 2 presented the percentages of choices and explanations for sub-topic 2 concerning the conception of motion in an electric field. The question three, four and five were designed to investigate students' understanding about charged particles in a uniform electric fields.

Table 2. Percentages of the choices and explanations for the questions 3, 4 and 5.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
3	UT	15.7	20.7	23.3	**38.8**	1.5	11.3	10.8	6.7	71.1
	GU	6.2	4.1	8.2	**81.4**	0.0	51.5	11.1	8.1	29.3
4	UT	**47.6**	19.7	22.1	9.6	1.1	10.2	10.2	6.9	75.9
	GU	**87.4**	2.1	7.4	3.2	0.0	44.4	8.1	7.1	40.4
5	UT	17.2	31.0	18.3	**32.3**	1.1	7.4	10.0	5.0	77.7
	GU	7.2	21.6	1.0	**70.1**	0.0	42.4	8.1	7.1	42.4

As shown in table 2, only about 40 percent of UT students were aware of that all the charged particles would move in a uniform electric field, the positive and negative charged particles would move to different direction in a uniform electric field, and the charged particles would accelerate in a uniform electric field. However, some UT students actually hold alternative conceptions. Some UT students thought that only positive charged particles would move and the others thought that only negative charged particles would move in a uniform electric field. And some UT students also thought that the charged particles would move with constant speed in a uniform electric field. It should be mentioned again that most of UT students did not provide explanations to support their choices. On the other hand, most of GU students could recognize the scientific conceptions and provide explanations to support their choices.

Table 3. Percentages of the choices and explanations for the questions 6, 7 and 8.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
6	UT	23.2	24.7	20.8	**30.0**	1.3	5.4	7.2	5.9	81.6
	GU	29.5	11.6	29.5	**29.5**	0.0	12.1	31.3	8.1	48.5
7	UT	**18.7**	16.9	25.7	37.6	1.1	1.5	11.9	4.6	82.0
	GU	**9.4**	11.5	19.8	59.4	0.0	4.0	39.4	6.1	50.5
8	UT	23.2	30.6	18.4	**26.5**	1.3	4.1	6.5	5.2	84.2
	GU	27.1	14.6	21.9	**36.5**	0.0	18.2	23.2	9.1	49.5

Table 3 presented the percentages of choices and explanations for sub-topic 3 concerning the conception of conductors and insulator in an electric field. The question six, seven and eight were designed to explore students' ideas about what happens when conductors and insulator inserted in a uniform electric field. As shown in table 3, only about 25 percent of UT students were aware of that no internal electric field exits in a metallic block in a uniform electric field, and electric field exists in an insulator block in a uniform electric field. However, some UT students indeed hold alternative conceptions. Some UT students thought that there was an internal electric field with the different magnitude and direction with external one. It should be noticed that both GU and UT students failed to recognize the correct answers in sub-topic 3 about conductors and insulator in an electric field. Besides, most of UT students did not provide explanations to support their choices, and many GU students provided wrong explanations to support their choices.

Table 4 presented the percentages of choices and explanations for sub-topic 4 concerning the conception of charge transfer. The question nine, ten and eleven were designed to investigate students' understanding about grounding.

Table 4. Percentages of the choices and explanations for the questions 9, 10 and 11.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
9	UT	27.3	**40.3**	20.0	10.8	1.5	9.5	7.4	5.4	77.7
	GU	9.1	**82.8**	5.1	3.0	0.0	56.6	10.1	1.0	32.3
10	UT	**43.0**	20.9	22.6	12.0	1.5	8.2	5.2	4.6	82.0
	GU	**77.8**	9.1	9.1	4.0	0.0	50.5	7.1	1.0	41.4
11	UT	18.2	23.9	23.9	**32.2**	1.7	6.1	5.0	4.1	84.8
	GU	4.1	6.2	6.2	**83.5**	0.0	41.4	6.1	3.0	49.5

As shown in table 4, about 40 percent of UT students were aware of that negative charge would move to the sphere or ground when connecting a positive or negative charged sphere to the ground. However, some UT students actually hold alternative conceptions. Some UT students thought that positive charge would move to the sphere or ground when connecting a positive or negative charged sphere to the ground. Other UT students also thought that there would be no charge transfer. On the other hand, most of GU students could recognize the scientific conceptions and provide explanations to support their choices. It should be mentioned that most of UT students did not provide explanations to support their choices.

Table 5. Percentages of the choices and explanations for the questions 12, 13 and 14.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
12	UT	29.3	17.3	**39.6**	12.0	1.7	5.9	6.5	5.9	81.8
	GU	24.5	2.0	**73.5**	0.0	0.0	27.3	22.2	6.1	44.4
13	UT	42.8	**21.4**	23.1	11.1	1.5	0.4	10.2	4.6	84.8
	GU	77.6	**10.2**	10.2	2.0	0.0	5.1	45.5	4.0	45.5
14	UT	19.2	25.7	**42.0**	11.1	1.9	3.9	6.3	5.2	84.6
	GU	9.2	15.3	**74.5**	1.0	0.0	17.2	32.3	3.0	47.5

Table 5 presented the percentages of choices and explanations for sub-topic 5 concerning the conception of work between equipotential lines. The question 12, 13 and 14 were designed to explore students' ideas about work and electrical potential energy. As shown in table 5, only about 34 percent of UT students were aware of that charged particles would create equal potential surfaces and in order to move any charged particle from one to other equipotential surface would need work to be done. However, some UT students indeed hold alternative conceptions. Some UT students were confused with the work and electrical force, they thought that the work to be done when the distance of two charges increased or decreased. In other words, the UT student preferred to use of reasoning based on the Newtonian model of action at a distance to solve problems[10]. It should be noticed that most of GU students could recognize the scientific conceptions. Besides, most of UT students did not provide explanations to support their choices.

Table 6 presented the percentages of choices and explanations for sub-topic 6 concerning the conception of charging and discharging in a DC circuit. The question 15, 16 and 17 were designed to investigate students' understanding about two metallic plates (charging of capacitors).

Table 6. Percentages of the choices and explanations for the questions 15, 16 and 17.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
15	UT	**47.6**	22.4	17.0	11.3	1.7	4.8	5.0	5.0	85.2
	GU	**67.7**	14.6	8.3	9.4	0.0	11.1	9.1	8.1	71.7
16	UT	32.4	25.6	13.6	**26.5**	.0	3.9	4.1	5.2	86.8
	GU	26.9	12.9	4.3%	**55.9**	0.0	16.2	6.1	7.1	70.7
17	UT	27.1	**31.9**	23.0	15.8	2.2	2.8	6.1	4.1	87.0
	GU	37.1	**25.8**	21.3	15.7	0.0	0.0	6.1	11.1	82.8

As shown in table 6, about 35 percent of UT students were aware of that two plates placed in constant distance would be charged when connecting to the battery. However, some UT students actually hold alternative conceptions. Some UT students thought that the plates connected to the positive pole of battery would be negative charged, and the plates connected to the negative pole of battery would be positive charged. Other students believed that two plates placed would still be charged even though filled some conduct matter between them. On the other hand, most of GU students could recognize the scientific conceptions.

Table 7. Percentages of the choices and explanations for the questions 18, 19 and 20.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
18	UT	13.5	12.2	35.7	**36.8**	1.7	11.1	6.9	4.1	77.9
	GU	5.1	1.0	40.4	**53.5**	0.0	30.3	14.1	3.0	52.5
19	UT	24.8	**39.9**	23.7	9.8	1.7	9.8	8.9	4.3	77.0
	GU	24.2	**50.5**	23.2	2.0	0.0	14.1	33.3	4.0	48.5
20	UT	21.9	**37.3**	27.3	11.4	1.7	5.9	8.2	4.1	81.8
	GU	21.6	**53.6**	24.7	0.0	0.0	8.1	24.2	5.1	62.6

Table 7 presented the percentages of choices and explanations for sub-topic 7 concerning the conception of current in a DC circuit. The question 18, 19 and 20 were designed to explore students' ideas about closed and open circuits. As shown in table 7, only about 38 percent of UT students were aware of that there was no current when the circuit is open. However, some UT students indeed hold alternative conceptions. Some UT students thought that the magnitude of current would be varied with size and temperature of the wire in a single circuit. And the bigger size and temperature of wire were, the smaller current was. They did not believe that there was the same magnitude of current in a single circuit no matter what the wire size and temperature were. It should be noticed again that most of GU students could recognize the scientific conceptions. Besides, most of UT students still did not provide explanations to support their choices.

Table 8 presented the percentages of choices and explanations for sub-topic 8 concerning the conception of charging and discharging of a capacitor. The question 15, 16 and 17 were designed to investigate students' understanding about current during the charging and discharging of the capacitor.

Table 8. Percentages of the choices and explanations for the questions 21, 22 and 23.

Item No	Group	Tier 1: Choices(%)					Tier 2: Explanations(%)			
		1	2	3	4	5	CE	WE	UE	NE
21	UT	22.5	13.3	**45.6**	16.2	2.4	7.2	8.7	4.3	79.8
	GU	25.0	14.6	**35.4**	25.0	0.0	10.1	24.2	3.0	62.6
22	UT	12.2	16.4	40.0	**29.3**	2.2	6.7	8.0	4.3	80.9
	GU	6.3	7.3	62.5	**24.0**	0.0	7.1	1.2	2.0	69.7
23	UT	11.0	20.0	**53.3**	13.4	2.4	8.5	5.0	3.9	82.6
	GU	7.3	6.3	**76.0**	10.4	0.0	17.2	8.1	3.0	71.7

As shown in table 8, about 43 percent of UT students could recognize the scientific conceptions. However, some UT students actually hold alternative conceptions. For example, any charged capacitor could be viewed as a battery even though the key of the circuit was closed. It should be mentioned that most of UT and GU students did not provide explanations to support their choices.

The different performance between UT and GU students in ECT

Figure 1 presented the proportion of UT and GU students who recognized the correct answers in ECT. Generally, the proportion of UT was 38 percent and the proportion of GU was 58 percent in ECT. And the performance of GU was better than UT in all eight sub-topics, especially in sub-topic 1, 2 and 4. So there was about 80 percent of GU students hold adequate electrical conceptions concerning electrical force, motion in an electric field and conductors and insulator in an electric field.

On the other hands, many UT students failed to recognize the correct answers in ECT. The highest proportion was in sub-topic 1, only about 55 percent of UT students could recognize the correct answers. But the proportion of other sub-topic was below 50 percent. It revealed that most of UT student did not hold adequate electric conceptions.

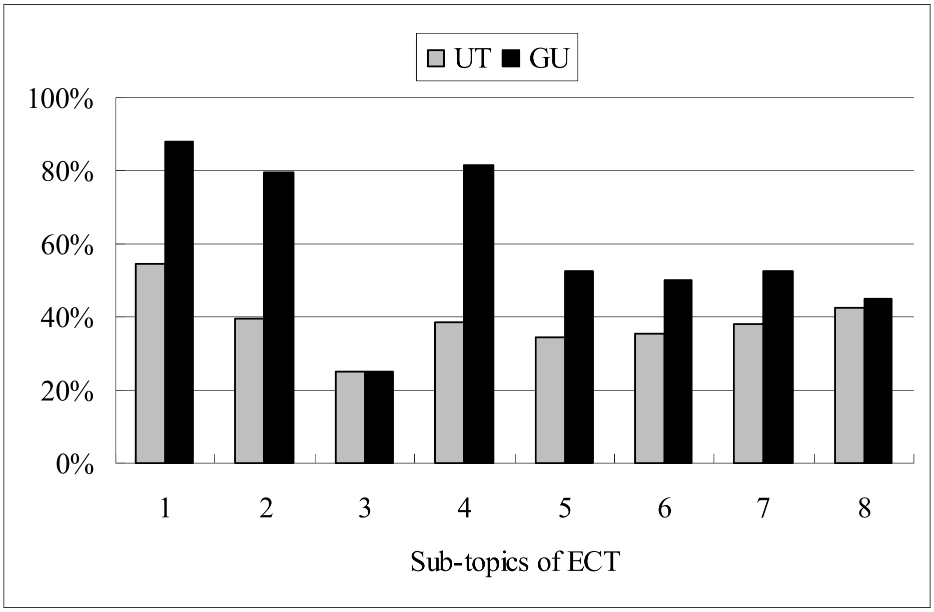

Fig 1. The performances of UT and GU students in ECT

Besides, both GU and UT students failed to recognize the correct answers in sub-topic 3 about conductors and insulator in an electric field. It revealed that there was only about 25 percent of UT and GU students hold adequate conceptions concerning conductors and insulator in an electric field. Based on our finding above, it is found that the GU students indeed outperformed than UT students in ECT.

The performance of different level UT students in ECT

In order to explore the performances of different level UT students further, we conducted the ANOVA to understand the performance of different level UT students in ECT. The participants were categorized as three groups(high-, H-UT; mid-, M-UT; low-, L-UT) by the scores in the integrated entrance examination of UT.

Table 9. The performances of different level UT students in sub-topic 1

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.79	0.41	66.38	.00**	(H-UT, M-UT) (M-UT, L-UT)
M-UT	0.52	0.50			
L-UT	0.34	0.48			
total	0.55	0.50			

**p < .01

The sub-topic 1 of ECT was designed about "Electrical force". Table 9 presented the different level students' performance in sub-topic 1 of ECT. Generally, the mean of all subjects was 0.55, it revealed that 55 percent of UT students hold adequate conceptions about "Electrical force". Furthermore, the mean of H-UT was higher than the other groups. And there were significant differences between H-UT, M-UT and L-UT. It revealed that the H-UT students hold more adequate conceptions about "Electrical force" than the M-UT and L-UT students.

Table 10. The performances of different level UT students in sub-topic 2

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.68	0.47	120.25	.00**	(H-UT, M-UT) (M-UT, L-UT)
M-UT	0.32	0.47			
L-UT	0.22	0.42			
total	0.40	0.49			

**p < .01

The sub-topic 2 of ECT was designed about "Motion in an electric field". Table 10 presented the different level students' performance in sub-topic 2 of ECT. Generally, the mean of all subjects was 0.40, it revealed that about 40 percent of UT students hold adequate conceptions about "Motion in an electric field". Furthermore, the mean of H-UT was higher than the other groups. And there were significant differences between H-UT, M-UT and L-UT. It revealed that the H-UT students hold more adequate conceptions about "Motion in an electric field" than the M-UT and L-UT students.

Table 11. The performances of different level UT students in sub-topic 3

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.35	0.48	18.85	.00**	(H-UT, M-UT) (H-UT, L-UT)
M-UT	0.18	0.39			
L-UT	0.24	0.43			
total	0.25	0.43			

**p < .01

The sub-topic 3 of ECT was designed about "Conductors and insulator in an electric field". Table 11 presented the different level students' performance in sub-topic 3 of ECT. Generally, the mean of all subjects was 0.25, it revealed that only 25 percent of UT students hold adequate conceptions about "Conductors and insulator in an electric field". Furthermore, the mean of H-UT was still higher than the other groups. And there were significant differences between H-UT and the other groups. It revealed that the H-UT students hold more adequate conceptions about "Motion in an electric field" than the M-UT and L-UT students.

Table 12. The performances of different level UT students in sub-topic 4

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.68	0.47	127.63	.00**	(H-UT, M-UT) (H-UT, L-UT)
M-UT	0.26	0.44			
L-UT	0.25	0.43			
total	0.39	0.49			

**p < .01

The sub-topic 4 of ECT was designed about "Charge transfer". Table 12 presented the different level students' performance in sub-topic 4 of ECT. Generally, the mean of all subjects was 0.39, it revealed that only 39 percent of UT students hold adequate conceptions about "Charge transfer". Furthermore, the mean of H-UT was still higher than the other groups. And there were significant differences between H-UT and the other groups. It revealed that the H-UT students hold more adequate conceptions about "Charge transfer" than the M-UT and L-UT students.

Table 13. The performances of different level UT students in sub-topic 5

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.40	0.49	4.33	.01*	(H-UT, M-UT) (H-UT, L-UT)
M-UT	0.32	0.47			
L-UT	0.32	0.47			
total	0.34	0.48			

*p < .05

The sub-topic 5 of ECT was designed about "Work between equipotential lines". Table 13 presented the different level students' performance in sub-topic 5 of ECT. Generally, the mean of all subjects was 0.34, it revealed that about 34 percent of UT students hold adequate conceptions about "Work between equipotential lines". Furthermore, the mean of H-UT was still higher than the other groups. And there were significant differences between H-UT and the other groups. It revealed that the H-UT students hold more adequate conceptions about "Work between equipotential lines" than the M-UT and L-UT students.

Table 14. The performances of different level UT students in sub-topic 6

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.52	0.50	41.33	.00**	(H-UT, M-UT) (M-UT, L-UT)
M-UT	0.31	0.46			
L-UT	0.24	0.42			
total	0.35	0.48			

**p < .01

The sub-topic 6 of ECT was designed about "Charging and discharging in a DC circuit". Table 14 presented the different level students' performance in sub-topic 6 of ECT. Generally, the mean of all subjects was 0.35, it revealed that about 35 percent of UT students hold adequate conceptions about "Charging and discharging in a DC circuit". Furthermore, the mean of H-UT was still higher than the other groups. And there were significant differences between H-UT, M-UT and L-UT. It revealed that the H-UT students hold more adequate conceptions about "Charging and discharging in a DC circuit" than the M-UT and L-UT students.

The sub-topic 7 of ECT was designed about "Current in a DC circuit". Table 15 presented the different level students' performance in sub-topic 7 of ECT. Generally, the mean of all subjects was 0.58, it revealed that about 58 percent of UT students hold adequate conceptions about "Current in a DC circuit". Furthermore, the mean of H-UT was still higher than the other groups. And there were significant differences between H-UT and the other groups. It revealed that the

H-UT students hold more adequate conceptions about "Charging and discharging in a DC circuit" than the M-UT and L-UT students.

Table 15. The performances of different level UT students in sub-topic 7

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.58	0.49	58.24	.00**	(H-UT, M-UT) (H-UT, L-UT)
M-UT	0.32	0.47			
L-UT	0.26	0.44			
total	0.38	0.49			

**p < .01

Table 16. The performances of different level UT students in sub-topic 8

Group	Mean	SD	F	*p*-value	Scheffe
H-UT	0.56	0.49	27.73	.00**	(H-UT, M-UT) (M-UT, L-UT)
M-UT	0.41	0.49			
L-UT	0.32	0.47			
total	0.43	0.49			

**p < .01

The sub-topic 8 of ECT was designed about "Charging and discharging of a capacitor". Table 15 presented the different level students' performance in sub-topic 8 of ECT. Generally, the mean of all subjects was 0.43, it revealed that about 43 percent of UT students hold adequate conceptions about "Charging and discharging of a capacitor". Furthermore, the mean of H-UT was still higher than the other groups. And there were significant differences between H-UT, M-UT and L-UT. It revealed that the H-UT students hold more adequate conceptions about "Charging and discharging of a capacitor" than the M-UT and L-UT students.

In sum, the mean of H-UT was higher than M-UT and L-UT in all sub-topic of ECT. The mean of M-UT was higher than L-UT in six sub-topic of ECT. And there were significant differences between H-UT, M-UT and L-UT. It revealed that the H-UT students hold more adequate electric conceptions than the M-UT and L-UT students.

Conclusion and Suggestion

In this study, we presented the engineering college students' conceptions of electricity. Furthermore, we also explore different level UT students' performances in ECT. Based on our results, four of these finding and one potential research issue are depicted bellow:

The UT students hold some alternative conceptions in Electricity

The UT students in Taiwan still hold many alternative conceptions in electricity. For example, the body having a larger charge would get more bigger force, the charged particles would move with constant speed in a uniform electric field, there was an internal electric field in a metallic block with the different magnitude and direction with external one in a uniform electric field, positive charge would move to the sphere or ground when connecting an positive or negative charged sphere to the ground, the magnitude of current in a single circuit concerned with wire size and temperature, etc. It should be mentioned that both GU and UT students failed to recognize the correct answers in sub-topic 3 about conductors and insulator in an electric field.

The GU students' performances were better than UT student in ECT

Generally, the proportion of UT was 38 percent and the proportion of GU was 58 percent in ECT. And the performance of GU is better than UT in eight sub-topics, especially in sub-topic 1, 2 and 4. So there was about 80 percent of GU students hold adequate electrical conceptions concerning electrical force, motion in an electric field and conductors and insulator in an electric field. Based on our finding above, it is found that the GU students indeed outperformed than UT students in ECT.

Students always lack of the ability/intention in reasoning and explanation

ECT was designed as two tier question. The participants were asked to write down their reasons and evidences for their choices in the second tier. In this study, only about 8 percent of UT students could provide correct explanations to support their choices. However, about 79 percent of UT students did not provide any explanations or ideas in the second tier of ECT. It is found that the UT students did lack of the ability/intention in reasoning and explanation.

The H-UT students outperformed than the other groups in ECT

The performances of different level UT student were what we concerned in this study. In order to explore the performances of different level UT students further, we conducted the ANOVA to understand the performance of different level UT students in ECT. The participants were categorized as three groups(high, H-UT; mid, M-UT; low, L-UT) by the scores in the integrated entrance examination of UT. After data analysis, it is found that there were significant differences between H-UT, M-UT and L-UT. It revealed that the H-UT students hold more adequate electric conceptions than the M-UT and L-UT students.

Future research issue: to develop more effective teaching strategy in the topics of electricity

Based on the findings of the present study, the students in universities of technology hold some alternative conceptions in Electricity. Therefore, the physics teacher should think how to teach the topics of electricity in an effective way. Furthermore, more research is need on developing more effective teaching strategy to enhance UT students' conception about electricity. Finally, it is found that the UT students did lack of the ability/intention in reasoning and explanation. It is suggested that physics teacher should encourage students and provide them more opportunities to engage in reasoning activities in physics course.

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