ELECTRICAL POTENTIAL – A STUDY ON STUDENTS UNDERSTANDING FOR BASIC PHYSICS IN ELECTRICAL ENGINEERING

A MASTER THESIS BY ULF NILSSON

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Abstract – *Basic concepts and definitions are often being overlooked in our goal to provide the students with a model, or a concept that can be useful for further studies in that area. This often results in an uncertainty that will have serious consequences in the way that the student reflects upon all areas that contain this model or concept. Electrical potential is one of the most important basic concepts in the field of electrical engineering. In our search for better learning methods we conducted a study on students understanding of that concept and our goal is to able us to further understand in what way the student perceive this concept and how the teaching change the perception.*

We observed that several students who had good intuitive understanding of the concept degenerated in their understanding during the course. This is not what the examiner of the course expected. However, if we look at the whole group most of the students gain understanding of the concept.

Introduction

Despite good skills in calculations we see that too many students have serious imperfections when it comes to understand basic concepts. In the teaching of electrical engineering and basic electrical physics some concepts seem to be more abstract then others [2][5], we believe that electrical potential is one of them. With these observations from both secondary school and university students, we made the query that is the base of this study.

When we look at different outcomes in learning [1] we see that the students can be subjected to superficial learning or a more solid deep learning. When we strive for deep learning with reflection capabilities we have to systemize the learning process in a way that makes the students think about their own learning process [4]. This is called Meta cognitive skills. Deep learning can be obtained in several ways, but they all have one thing as common ground, reflection. Reflection is essential in deep learning and Meta cognitive skills [1][4].

The object with the query was to give us further information about the students understanding for basic physical concepts. With this information we hoped to be able to further develop the teaching and course context in this introductory courses in circuit analysis. We wanted the selected students for the study to be a representative group for more master programs than just electrical engineering. Therefore we used a master program called Automation & Mechatronics at Chalmers University of Technology. The students were attending their first year in this master program and their first course in circuit analysis. This gave us the opportunity to see what the students know in this area from secondary school.

Method

We decided to use electrical potential because it is a concept we believed to be more often overlooked than charge, current or voltage in the learning process of circuit analysis. Instead of using a textbook or a dictionary [3] for the definition of electrical potential we used three test-groups of teachers and none educational persons to derive the three questions that the query contains. The object with this was to get a better overall view of the concept electrical potential.

The three test groups were asked what the best analogy would be for electrical potential in terms of an other physical concept. The three test-groups where *teachers/ scientists at technical universities, teachers at secondary schools and the public.* In the first two groups all participants where involved in electrical education of some kind, this was to insure the accuracy in the answers. In the last group called *the public* there where none involved in the area of electrical engineering, this was to insure a broad perspective. All together fifteen persons were asked, five from each group. The first question in the query was based on the answers we got from these test-groups. The answers were grouped in to three groups and that became the model for the assessment on all the questions. The quality of the answers was measured with help of the test groups. The best answers were assumed to be found in the group *teachers/scientists at technical universities* and the second best answers to be found in the group *teachers at secondary schools.* In the last group *the public* we assumed that the least good answers would be found. When an answer was found in different groups it was grouped in the first group on the quality scale. The following two questions on the query had a more open character. The second question was to reveal the students understanding for the difference

between electrical potential and voltage. The third question was to reveal the students capability to reflect upon the concept of electrical potential.

The students did the query two times, first time at the start of the course and the second time at the end of the course. The course started in November 2001 and finished in March 2002. An oral comment was done both times. It was clarified that it was the best analogy we looked for in the first question and nothing else. The students had about 10 minutes to answer the three questions. At the first time 85 students answered the query and at the second time 51 students answered. The differences in number of participants the two times can be a normal change in number of participants at the lectures from the beginning of a course to the end of it.

The query and the assessment criteria

The query contains three questions, which were used to reveal the students understanding for the concept electrical potential. The assessment criteria are individually based for each question.

First question

The first question is a complex form of multiple-choice question where the student shall number three options in falling order with the numbers 1 to 3, where 1 is the best analogy in falling order to 3. The ten answers the student could choose from were derived from TABLE A below.

The question the participants in the test-groups were asked was: If you have to compare electrical potential with some other physical concepts, which one of them would you choose?

TABLE A

Person	Teachers/scientists at technical universities	Teachers at secondary school	The public
1	Potential energy and with a comparison with height	Potential energy	Don't know
2	Potential energy, pressure and temperature	Voltage in one point referred to ground	Voltage and current?
3	Potential energy	Clustered charges	Don't know
4	Gravitation potential and a comparison between an orienteers map and a circuit	Potential energy	It is something electrical, resistance?
5	Potential energy	Potential energy with a comparison to height	Don't know

As the third group *the public* had a hard time to answer anything we added three answers that were wrong. They were: Active power, Charges in motion and mass. The three groups that were derived from TABLE A are shown below.

Group one: Potential energy, Temperature and Pressure.
Group two: Clustered charges and Voltage.
Group three: Active power, Charges in motion, Mass, Resistance and Current.

In Group one we find the best answer with falling order to Group three. Observe that the groups are not the same as the number sequence the students answered the first question with.

Assessment criteria

Good understanding: 1 and 2 is in group one and 3 in group one or group two.

Some understanding: Anyone of 1 to 3 is in group one and at least one in group 2. 1 is not allowed to be in group three.

Weak understanding: 1 and/or 2 is in group three, or no answer.

Second question

The second question is of a more open character, with a yes or no answer followed by a motivation. The question:

Is there any difference between voltage and electrical potential? If so, what is the difference?

The question seamed further motivated because observations done in class indicated that it was a problem for many students to differentiate the two.

Assessment criteria

Structure on the answer: Yes/No, and motivation.

Good understanding: Yes, and a motivation that indicates good understanding.

Some understanding: Yes, and a motivation that indicates some understanding.

Weak understanding: No / Wrong motivation / No answer.

Third question

The third question was of an open character with only one restriction. The question was not allowed to be more than one sentence. The question:

Describe electrical potential with your own words in one sentence.

The question was made to see what free associations the students had about the concept. The assessment criteria may seem vaguely constructed but they are open in their character so the assessment can consider different perspectives in understanding.

Assessment criteria

Good understanding: A correct description.

Some understanding: A description that shows some understanding.

Weak understanding: A description that shows weak or no understanding / no answer.

In all assessments above, quality of the answers have been measured not the quantity. The assessments were done with a hermeneutic method, part and over all perspective.

Analysis of the query

The fact that the query had 85 participants the first time and only 51 participants the second time creates an uncertainty. Some observations can also be made about the difference between the groups of participants the two times the query was done, the students above 25 years of age and females. There were 4 % decrease in female participants and no one was over 25 years of age the second time. There were 8 participants over 25 years of age the first time. After more investigation of these two groups it was clear that they were representative for the rest of the group. From this we will assume the 51 participants the second time to be a representative and valid group of the 85 participants the first time.

Results

The results are presented both in table- and diagram form. The values within parenthesis have been multiplied with the quotient 85/51 to be more accurate in the percent calculations. All percent values down below are calculated with the compensated values. In all three question-diagrams for the second time the query was done, we see the compensated values in the parenthesis.

Results of the first question

First question first time

TABLE I

Level of understanding	Number
Good understanding	15
Some understanding	22
Weak understanding	48

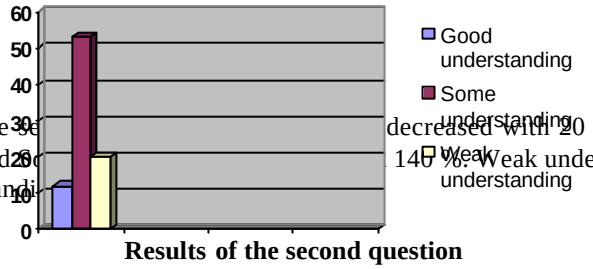
DIAGRAM I

First question second time

TABLE II

Level of understanding	Number
Good understanding	7 (12)
Some understanding	32 (53)
Weak understanding	12 (20)

DIAGRAM II



We see decreased with 20 % and 140 %. Weak understanding

Second question first time

TABLE III

Level of understanding	Number
Good understanding	5
Some understanding	31
Weak understanding	49

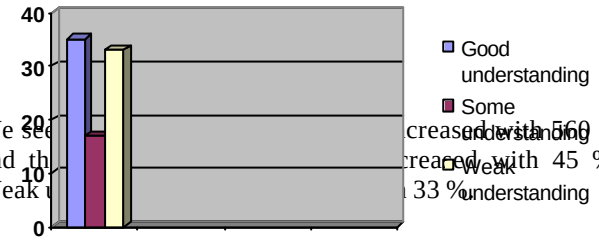
DIAGRAM III

Second question second time

TABLE IV

Level of understanding	Number
Good understanding	21 (35)
Some understanding	10 (17)
Weak understanding	20 (33)

DIAGRAM IV



We see that Good understanding has increased with 560 % and that Some understanding has decreased with 45 %. Weak understanding has decreased with 33 %.

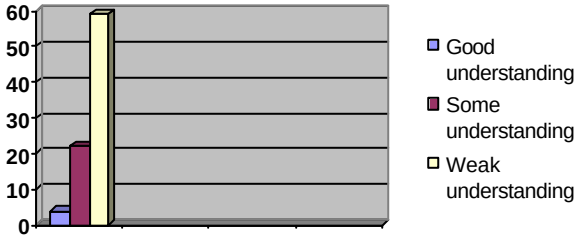
Results of the third question

Third question first time

TABLE V

Level of understanding	Number
Good understanding	4
Some understanding	22
Weak understanding	59

DIAGRAM V

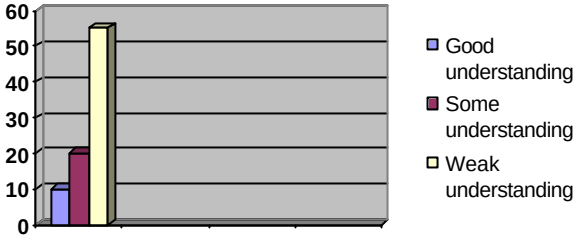


Third question second time

TABLE VI

Level of understanding	Number
Good understanding	6 (10)
Some understanding	12 (20)
Weak understanding	33 (55)

DIAGRAM VI



We see that Good understanding has increased with 150 % and that Some understanding has decreased with 9 %. Weak understanding has decreased with 7 %.

Special observations

In the study we have especially studied how many of the participants who answered potential energy and voltage in the first question the first time. It was of special interest because if you put any of these answers in the right perspective it can tell you in what way the students look at the concept of electrical potential, from a physical point of view or from a circuit point of view. Potential energy represents the physical view and voltage the circuit view.

TABLE B

	Answers	
Order	Potential energy	Voltage
1	23	13
2	10	26
3	4	17

Some different answers to the second- and third question

- ”Electrical potential is the difference in voltage” (second question)
- ”Electrical potential is the voltage in a special point” (second question)
- ”Electrical potential is voltage to earth” (second question)
- ”Some of the total voltage have been lost” (third question)
- ”The charges energy in an electrical field” (third question)
- ”Electrical potential is the voltage between circuit and earth” (third question)
- ”Electrical potential energy” (third question)

It is common that the students understanding for electrical potential is based on the use of Kirchhoff’s voltage method. This rarely leads to any energy discussions or other creative points of view.

Discussion about the results

The discussion is divided into four parts, the three first are the questions separately in falling order and the forth is an overall perspective.

First question

When we look at the results we see that the largest difference between the first time and the second time was in the middle group that is called Some understanding. There was an increase with 140 %, which indicates that most of the students gained understanding during the course. The students task was to answer the question with the best analogy, so it is not only the vocabulary that has improved during the course. To answer with a better analogy the second time can be the result of two things, the student has learnt one or a few by heart or the student can now reflect upon the problem and make a better choice.

If we look at the last group called Weak understanding there has been a decrease with 58 %. We can see in TABLE I that it was 48 of the participants that had Weak understanding when they enrolled in the course and in TABLE II that it was 12 (20) the second time the query was done at the end of the course. We can conclude that most of the decrease in the group Weak understanding is transferred to the increase in the group Some understanding.

We also see that there are some indications in the group Good understanding that the students with good intuition or understanding of the physical concept electrical potential degenerate in their understanding. If we compare with the other two questions they had a much larger increase in the group Good understanding the second time the query was done, this strengthen the indication about the degeneration.

Second question

When we look at the results of the second question we see that there is a large difference between the first time and the second time in the first group that is called Good understanding. The increase was 560 % and that can be derived to the decrease in the other two groups. When we look back at the questions character we see that it's open in the second part but is restricted in the first Yes- or No part. The second part requires an indication to good understanding for the physical view of electrical potential. If the criterias are met the students are grouped into the group called Good understanding. The large increase must be put in the perspective that it was only 5 participants the first time they answered the question that qualified in to the group called Good understanding. If we investigate how many percentage of the total group that qualified in to the group Good understanding the second time it is 41 %. The group Weak understanding has decreased but it's still 39 % left in this group after the second time the study was done.

Under Special observation we see some special observations, and among them some of the answers that the students had to the question.

- "Electrical potential is the difference in voltage"

We see that the student try to repeat something he actually don't know especially well. The definition we find in many physic books from secondary school is $U_{AB} = V_B - V_A$ where U is voltage and V is the electrical potential so we say that voltage is the difference in potential. The student cannot differ the two, and the mistake is easily done.

- "Electrical potential is the voltage in a special point"

The student who answer the question in this manner have a circuit perspective and that can be a good thing if there is some indication that the student also understand the concept electrical potential in more physical based view. But, if the student answers like above we can conclude that the student doesn't feel secure in their understanding of electrical potential. The insecurity the student may have can be seen because the student tries to define electrical potential with the more familiar voltage concept. It is not unusual to meet well educated people in the area of electrical engineering who are uncertain of the concept electrical potential, so it's not so strange that the first year students have some difficulty with this concept.

We can see that the concept of electrical potential almost can take on mysterious proportions for the student and that is damaging to the students capability to reflect on every area that in some way need the concept electrical potential, which are quite a few areas.

Third question

When we look at DIAGRAM V and DIAGRAM VI we see that there is not any dramatic change in any of the groups. We have an increase with 7 % in the group called Good understanding and a 2 % decrease in the group called Some understanding. Most of the students meet the criteria for the group called Weak understanding. It is of special interest that the group Weak understanding still is high the second time. It may be a difficult form of question to answer. It is very open in its character and that may be one of the reasons that over 60 % of the group didn't indicate adequate understanding for the question. To meet the criteria you must show in your own words that you understand the concept and this also may be an indication that the concept of electrical potential is neglected both from secondary school and at university level. Students with weak understanding tend to have a hard time to reflect upon the matter at hand. As the results from the third question indicates that many of the students either skip the

question or repeat the answer from the second question, which only rarely meet the criterias for the third question.

As Henk Vos, 2002 points out in his Ph. D. thesis Metacognition in Higher Education teachers should try to systemize the training of meta cognitive skills in the students learning process. If we do so, the students will be more skillful in the area of reflection and analyzing their own learning process. I believe that this would help many of the students to answer a question like the third on the query. If you can reflect upon your own knowledge you have a better chance to find somewhere to start your answer and not skip it because you couldn't remember any answer to it.

Under Special observation we see some special observations, and among them some of the answers that the students had to the question.

- "Some of the total voltage have been lost"

If we look at the answer above and recall the question: Describe electrical potential with your own words in one sentence. At the first look you may think that the answer has no relevance at all, but if we start to think in an energy perspective it make more sense. If we then look at a circuit view and take an energy perspective we may find some understanding for what the student meant. All answers were not of the character as the one above. The next answer is a better one.

- "The charges energy in an electrical field"

It could of course be more specific, what kind of charges, what reference and so on, but it indicates that the student thinks in a physical way and probably can disclose the matter better than most of the students in a discussion.

Overall perspective

Some observations are more interesting than others. If we look at a few of the most interesting, we first see that many of the students seam to change there understanding from Weak understanding to Some understanding or Good understanding. We also see some indication that the students who had good intuition or understanding when they enrolled in the course degenerate in their understanding during the course. Worth pointing out is that it seems that a large group of the students have problems to describe electrical potential with their own words even after the course. This may be an implication of the way the students look at their own knowledge and learning process [4]. If the students only think of passing the exam, there is a problem in their learning process. The students must be motivated to really learn for life not only for the exam.

Conclusions

We can draw some conclusions about the students understanding and how we can help them understand basic concepts better. We observe that many of the students try to repeat something they remember badly and don't try to reflect upon the problem. We also see that the course made some students lose confidence in their intuition. We should take notice of these observations and try to systemize ways in teaching to help the students to reflect upon problems instead of just remembering them. One way to do this would be to have the students do tests like the query and then discuss the results and the questions in small groups. This would give the student time to reflect upon the question and the learning process. The method with the three test-groups increased the validity of the study and gave interesting results.

Acknowledgement

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