AAEE 2012 CONFERENCE
Melbourne, Australia
www.aaee.com.au/conferences/2012/

Students' understanding about the brightness of light bulbs connected in DC electric circuits

Suchai N.[a,b] and Thasaneeya R. N.[a]
Institute for Innovative Learning[a] and Department of Physics, Faculty of Science[b], Mahidol University, Thailand
Corresponding Author Email: thasaneeya.rat@mahidol.ac.th

BACKGROUND
DC simple electric circuits are an important topic in the curricula of secondary school and university level in many countries. Studies of students' conceptually difficult knowledge − a kind of troublesome knowledge about this topic were found in a number of research and revealed that the more researcher used the test with their students, the more misconceptions were found. This could help teachers assist their students to gain understanding of the concept or create appropriate, targeted teaching responses to learners' difficulties.

PURPOSE
The purpose of this study was to investigate first year undergraduate students' misconceptions about the brightness of identical light bulbs connected in DC electric circuits. A survey was developed based on the misconceptions found in a group of science and technology education master degree students. The misconceptions will be used as a guideline to design a teaching module to teach the undergraduate students in the second semester.

DESIGN/METHOD
Eight True False questions were created, based on international master degree students' misconceptions about the brightness of identical light bulbs connected in DC electric circuits. These questions were used to survey 209 first year undergraduate students' misconceptions. Students' responses are analysed in terms of students' pattern of thinking, students' misconceptions, and students' scientific problem solving skill.

RESULTS
Misconceptions about the brightness of light bulbs connected in DC electric circuits previously reported were found in this research, such as 1) the brightness of the identical light bulbs connected in a series circuit are not the same. 2) the nearer the battery, the brighter the light bulb. In addition, a specific misconception peculiar to our students existed within those surveyed. The students thought that a connection of the light bulbs in a main (same) line is always a series circuit even some of them are connected in parallel with another bulb. This idea was found when students gave a reason to support their response about the brightness of light bulbs in main line are the same; the reason is because the bulbs are connected in a series circuit.

CONCLUSIONS
The misconceptions about the brightness of light bulbs connected in DC electric circuits as 1) the brightness of identical light bulbs connected in a series circuit are not the same and 2) the nearer the battery, the brighter the light bulb found in a group of science and technology education master degree students are also found in a group of first year undergraduate students. In addition, students in both groups have considerable difficulty in interpreting series analysis in a more complex circuit.

KEYWORDS
Misconceptions, Series and Parallel circuit, Brightness.

BACKGROUND

Students are familiar with brightness of a light bulb, and the concepts of series and parallel circuits. Many students have used a torchlight since childhood. They know that the more batteries that are used in series with a torch bulb, the brighter the light produced. When students grow up, they are taught concepts about series and parallel circuits more than one time since they were the secondary level students. They learn the different properties (voltage across and current passing through electric components), the schematic diagrams of both circuits, and Ohm's law. These are the "threshold concepts" to opening up a new dimension of students' understanding of the "complex concept" (Carstensen & Bernhard, 2007) about the brightness of the identical light bulbs connected in series and parallel circuits.

Research about students' misconceptions of DC electric circuits has revealed that students have many misconceptions. These include: 1) current, energy, and potential difference are not considered to be different concepts and are used interchangeably with each other; 2) current is consumed by circuit components; 3) current comes out from the (+) pole of the battery and enters to the bulb where it is consumed to light the bulb; the second wire connected between the (-) pole and the bulb serves no purpose; 4) current comes out from the both poles of the battery and clashes in the bulb to light it; 5) current is divided equally in each branch of a parallel circuit; 6) a change before the bulb affects the brightness of the bulb in circuit connected in series but the same bulb is not affected by change in anywhere of the circuit after the bulb; and 7) batteries are constant current sources (Küçüközer & Kocakülah, 2007).

It appears true that the more research about students' misconceptions are implemented, the more misconceptions are found as many researchers reported that some specific misconceptions were identified in their research (Ates, 2005; Engelhardt & Beichner, 2004; Joel & Carol, 2006; O'Dwyer, 2009). However, the misconception that "current is consumed by circuit components", which is the second example above, is reported in almost all research (Küçüközer & Kocakülah, 2007). This might because it is easy for students to accept the idea that circuit components need some input to give an output. In other words, it is hard to believe that the amount of current before and after a light bulb are the same. This kind of knowledge was named as "Conceptually Difficult Knowledge" which is a part of "troublesome knowledge − knowledge that is 'alien', or counter-intuitive or even intellectually absurd at face value." as presented in (J.H.F. Meyer & Land, 2003; Land, Cousin, Mayer, & Davies, 2005; Perkins, 1999)

Understanding troublesome knowledge could help teachers assist their students to gain an understanding of such concepts (J.H.F. Meyer & Land, 2003) or create appropriate, targeted teaching approaches that respond to learners' difficulties (Land et al., 2005; Perkins, 1999). Perkins (1999) suggests the appropriate teaching approach for "Conceptually Difficult Knowledge" is an arrangement of inquiry processes that confront students with discrepancies in their initial theories – either discrepancies between theory and observations or logical discrepancies.

In the authors' physics course, questions about the brightness of two identical light bulbs connected in a series and a parallel circuit as used in (Küçüközer & Demirci, 2005) were introduced to eight international master degree students in a class about "misconceptions". This was done as the authors wanted the students to learn from their firsthand experience: the meaning of misconceptions, source of misconceptions, and how misconceptions could be changed. Even though our students had taught physics at the high school level for many years, some of them still had the misconception that "current is consumed by circuit components". Their responses to the question about brightness of the two identical light bulbs connected in a series circuit (see Figure 1) was "the brightness of L1 is brighter than that of L2 because L1 is nearer the battery than L2". However, they could give the correct response for a parallel circuit.

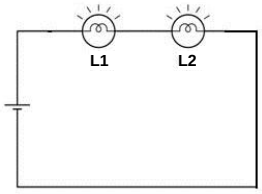


Figure 1: Two identical light bulbs connected in a series circuit.

Rather than tell the students directly that they had a misconception, the authors proposed the following question as a hint: consider the brightness of a one light bulb circuit with different number of batteries. This hint could help students realise that increasing the voltage across or current passing through the bulb makes increases the brightness of the bulb. Students then were encouraged to think about the current passing through and voltage across the two identical resistors connected in a series circuit that equivalent to the light bulbs circuit as shown in Figure 1. After a few minutes, students were able to relate a more familiar (resistors) circuit to the light bulbs circuit. Finally, they could change their misconception of "current is consumed by circuit components". This success supports the Perkin's idea to use an inquiry process to respond students' conceptually difficult knowledge.

The authors also challenged students with a more complicated DC electric circuit to investigate whether the students were able to apply these newly learned concepts. Students were asked to rank the brightness of the seven identical light bulbs connected in a circuit as shown in Figure 2. The study offered some fascinating results to researchers. Almost all students tried to calculate the voltage across and current passing through each light bulb rather than simply thinking about how the current flows in the circuit. Some students responded that the brightness of L1, L2, L4, L5, and L6 were the same because they were connected in a series circuit. These students also explained that these light bulbs were connected in a (same) line as they had perceived in a circuit of two resistors connected in series (see Figure 3).

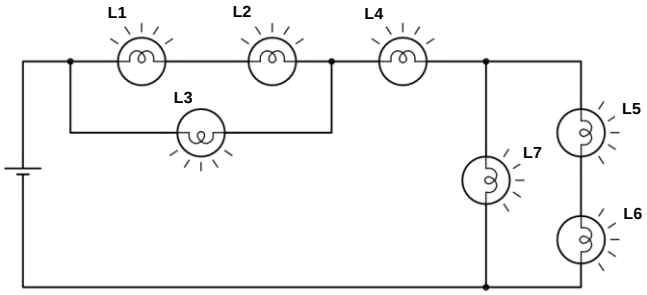


Figure 2: Circuit used to investigate students' ability to apply the newly concept.

The students' responses were quite different to the authors' expectations and made the authors eager to know whether only this group of students had this misconception or whether other students also had it. To investigate this further, the authors developed a conceptual test of eight True False questions (see Appendix) based on the misconceptions found from this group of students to introduce to first year undergraduate students.

PURPOSE

The purpose of this study was to survey first year undergraduate students' misconceptions about the brightness of light bulbs connected in DC electric circuits based on the misconceptions found in the group of science and technology education master degree students. The misconceptions will be used as a guideline to design a teaching module to teach the undergraduate students in the second semester.

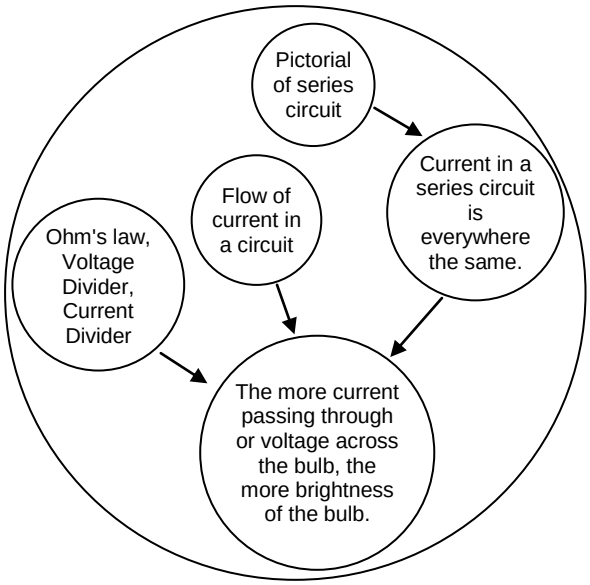


Figure 3: Model of students' possible methods to solve the challenging problem. Authors used the idea suggested by Carstensen and Bernhard (2007) to create this model.

DESIGN/METHOD

The objective of this research was to investigate whether master degree students' misconceptions about the brightness of light bulbs connected in DC electric circuits are also common in first year undergraduate students. To test this idea, the authors developed an evaluation test consisting of eight True False questions as shown in the Appendix. The misconceptions covered in the evaluation were 1) brightness of the identical light bulbs connected in series are not the same 2) the nearer the battery, the brighter the light bulb and 3) the brightness of L1, L2, L4, L5, and L6 in Figure 2 are the same because they are connected in a series circuit.

The participants were 209 Thai first-year undergraduate students who attend an introductory physics course in the first semester of the 2012 academic year. The class was taught by another lecturer who was interested in the misconceptions mentioned above, especially the third misconception. The lecturer was not a member of the research group the authors are members of. However, the lecturer and authors agreed to use only a small amount of class time to collect the data. This was because the topic of DC electric circuits is not included in the first semester syllabus. Therefore, the evaluation was designed as a True False question format because this type of question format 1) is easier to administer and analyse than free-form descriptive format 2) is especially useful for questions where there are only two reasonable answers and 3) is able to expressed in few words, making the questions easier to understand and less dependent on reading ability (The Office of Measurement Services: The University of Minnesota, 2011).

Participants had 15 minutes to respond to the eight True False questions, individually, before their class started. They also knew that their responses would not affect their class score but the results would be used to design a teaching module that would be used to teach them in the next semester.

The students' responses were grouped and analysed in terms of 1) students' thinking pattern; only the group of response that have more than 5% of total students in the group were interpreted as a thinking pattern and 2) students' misconceptions that have been mentioned in the first paragraph of this section; the number of students' responses to a group of questions matching a criteria would be counted i.e. if students' responses to the first, third, and fourth questions were "**×**", then it is assumed that the students believe that brightness of identical light bulbs connected in series are not the same.

RESULTS

Five groups of students' thinking patterns and the number of students in each group are shown in Table 1. The results revealed that 1) 7.2 % of the students responded to all questions as "×" 2) 10% of the students are classified as "having correct understanding" because they could give the correct responses for all questions 3) 13% of the students did not know that the brightness of identical light bulbs connected in series are the same and they also had the idea that the nearer the battery, the brighter the light bulbs 4) 18.2% of the students knew that brightness of identical light bulbs connected in series are the same but they had a misconception that L1, L2, L4, L5, and L6 are connected in a series circuit 5) 12% of the students have the same understanding as that of the 4th group and they also believed that L3, L4, and L7 are connected in a series circuit.

Table 1: Students' thinking patterns and their meaning

Gr.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	No.	Interpretation
1	×	×	×	×	×	×	×	×	15	• Not able to interpret.
2	✓	×	✓	✓	×	×	×	×	21	• Having a correct understanding.
3	×	×	×	×	×	×	✓	✓	27	• Having no idea that the brightness of the light bulbs connected in a series circuit are the same. • Having a misconception that the nearer the battery, the brighter the light bulb.
4	✓	×	✓	✓	×	✓	×	×	38	• Having an idea that brightness of the light bulbs connected in a series circuit are the same. • Having a misconception that L1, L2, L4, L5, and L6 are connected in a series circuit.
5	✓	×	✓	✓	✓	✓	×	×	25	• Having the same ideas as students in the 4th group. • Having a misconception that L3, L4, and L7 are connected in a series circuit.

Table 2 shows the number (No.) and the response pattern (Pattern) of the students who had the misconceptions that were mentioned in the first paragraph of the design/method section. Results revealed that 1) 31.1% of the students believed that the brightness of light bulbs connected in series circuit are not the same (P1). 2) 22.5% of the students had the idea that brightness of the light bulb was inverse proportional to a distance between the bulb and the battery (P2). 3) 39.2% of the students had a misconception about the connection between light bulbs; they believed that L3, L4, and L7 and/or L1, L2, L4, L5, and L6 were connected in a series circuit (P3-P5).

Table 2: Pattern of students' response and their misconception (N can be "✓" or "×")

Pattern	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	No.	Misconception
P1	×	**N**	×	×	**N**	**N**	**N**	**N**	65	• Brightness of the identical light bulbs connected in series are not the same.
P2	**N**	**N**	**N**	**N**	**N**	**N**	✓	✓	47	• The nearer the battery, the brighter the light bulb.
P3	✓	**N**	✓	✓	×	✓	**N**	**N**	51	• L1, L2, L4, L5, and L6 are connected in a series circuit.
P4	✓	**N**	✓	✓	✓	×	**N**	**N**	6	• L3, L4, and L7 are connected in a series circuit.
P5	✓	**N**	✓	✓	✓	✓	**N**	**N**	25	• Both of the 3rd and 4th misconceptions.

In addition, some pattern of students' responses can represent their "scientific problem solving skill", which is the ability to consistently use a concept to solve the set of problems (Nopparatjamjomras, 2008). In this research, students who gave the same response for the first, third, fourth, fifth, and sixth questions have a scientific problem solving skill. If the students' responses to the first, third, and fourth questions were "×" then they have the idea that brightness of the identical light bulbs connected in series are not the same, their responses to the fifth and sixth questions will be "×". On the other hand, if students knew that brightness of the identical light bulbs connected in a series are the same (their responses to the first, third, and fourth questions should be "✓") and if they believed that the connection of L3, L4, and L7 together with that of L1, L2, L4, L5, and L6 are in series, their responses to the fifth and sixth questions will be "✓". Table 3 shows the number of students who were considered to have a scientific problem solving skill.

Table 3: Response pattern of the students who have "scientific problem solving skill".

Pattern	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	No.
P1	×	**N**	×	×	×	×	**N**	**N**	54
P2	✓	**N**	✓	✓	✓	✓	**N**	**N**	25

Furthermore, there are only nine students (4.3%) that could not give the correct response to the second question. This probably means that almost all students did not have a problem with parallel circuits.

CONCLUSIONS

The misconceptions concerning the brightness of light bulbs connected in DC electric circuits found in a group of science and technology education master degree students were also found in a group of 209 first year undergraduate students. These misconceptions consist of the misconceptions that have been already reported by other researchers as 1) the brightness of identical light bulbs connected in a series circuit are not the same and 2) the nearer the battery, the brighter the light bulb. In addition, the specific misconception identified with our students that existed within those surveyed is that the brightness of L1, L2, L4, L5, and L6 in the circuit shown in Figure 2 are the same because students thought that the bulbs are connected in a series circuit. Authors will use these misconceptions to design a teaching module to teach the undergraduate students in the second semester.

References

Ates, S. (2005). The effects of learning cycle on college students' understandings of different aspects in resistive DC circuits. *Electronic Journal of Science Education, 9*(4).

Carstensen, A.-K., & Bernhard, J. (2007). Threshold Concepts and Keys to the Portal of Understanding: Some Examples from Electrical Engineering. In R. Land, J. H. F. Meyer & J. Smith (Eds.), *Threshold Concepts within the Disciplines* (pp. 143-154). The Netherlands: Sense Publishers.

Engelhardt, P. V., & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics, 72*(1), 98-115.

J.H.F. Meyer, & Land, R. (2003). Threshold Concepts and Troublesome Knowledge: Linkages to Ways of Thinking and Practising within the Disciplines *Enhancing Teaching-Learning Environments in Undergraduate Courses Project*. Edinburgh: University of Edinburgh.

Joel, A. B., & Carol, S. (2006). The 'Brightness Rules' alternative conception for light bulb circuits. *Physics Education, 41*(6), 522-531.

Küçüközer, H., & Demirci, N. (2005, September, 13rd-16th). High School Physics Teachers' Forms of Thought about Simple Electric Circuits. *23th International Physics Congress,* 733-738.

Küçüközer, H., & Kocakülah, S. (2007). Secondary School Students' Misconceptions about Simple Electric Circuits. *Journal of Turkish Science Education, 4*(1), 101-115.

Land, R., Cousin, G., Mayer, J. H. F., & Davies, P. (2005). Threshold Concepts and Troublesome Knowledge (3): Implications for Course Design and Evaluation. In C. Rust (Ed.), *Improving Student Learning: Diversity and Inclusivity* (pp. 53-64). Birmingham: Oxford Centre for Staff and Learning Development (OCSLD).

Nopparatjamjomras, S. (2008). *A New Approach to Teach Colored Light and Color Perception for High School Students by Using Colored Light Mixer.* Doctor of Philosophy (Science and Technology Education), Mahidol, Bangkok.

O'Dwyer, A. (2009). *Prior understanding of basic electrical circuit concepts by first year engineering students*. Paper presented at the All-Ireland Society for Higher Education (AISHE) Conference, NUI Maynooth.

Perkins, D. (1999). The many faces of constructivism. *Educational Leadership, 53*(7), 6-11.

The Office of Measurement Services: The University of Minnesota. (2011, August 05, 2011). Writting True-False Items Retrieved June, 30, 2012, from http://oms.umn.edu/fce/how_to_write/truefalse.php

Acknowledgements

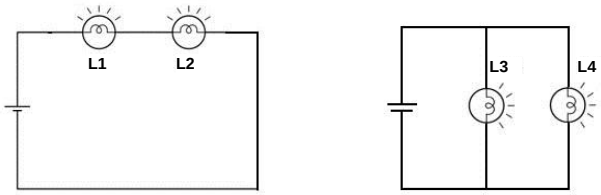
Authors would like to present our gratitude to the Thailand Research Fund (TRF) and the office of National Research Council of Thailand (NRCT) for supporting research grants. These contributions motivate authors to develop science learning and teaching materials for improve students' understanding in the future. The useful comments from reviewers of AAEE in peer-review process helped authors to develop this paper. Finally, the authors also would like to thank the Engineering and Science Education Research (ESER) group and Faculty of Engineering and Industrial Sciences, Swinburne University of Technology; and Faculty of Graduate Studies, Mahidol University for financial support of this presentation.

Appendix

BRIGHTNESS OF THE LIGHT BULBS IN THE DC CIRCUIT CONCEPTUAL EVALUATION

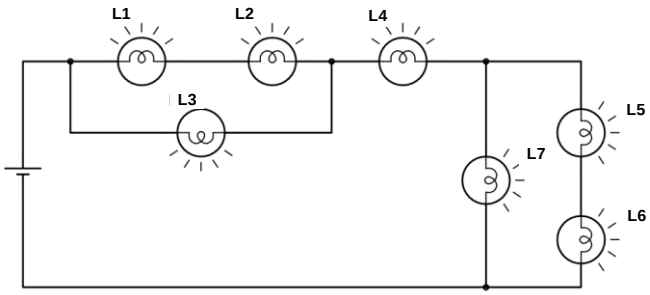
Please give the answer yourself in 15 minutes. Your response will be used for science and technology education research (Physics education) only. It will not effect to your classroom score.

Instruction All light bulbs are identical and the batteries are perfect (They can supply enough energy for all device)



From the above circuits, please mark ✓ or ✗ in front of the question that you thought it is **"correct"** or "**incorrect"**, respectively.

____1. The brightness of L1 is same as that of L2 because L1 and L2 are connected in a series circuit.
____2. The brightness of L3 is brighter than that of L4 because L3 is nearer the battery than L4.



From the above circuits, please mark ✓ or ✗ in front of the question that you thought it is **"correct"** or "**incorrect"**, respectively.

____3. The brightness of L1 is same as that of L2 because L1 and L2 are connected in a series circuit.
____4. The brightness of L5 is same as that of L6 because L5 and L6 are connected in a series circuit.
____5. The brightness of L3, L4 and L7 are the same because L3, L4 and L7 are connected in a series circuit.
____6. The brightness of L1, L2, L4, L5 and L6 are the same because L1, L2, L4, L5 and L6 are connected in a series circuit.
____7. The brightness of L1 is brighter than that of L5 because L1 is nearer the battery than L5.
____8. The brightness of L3 is brighter than that of L7 because L3 is nearer the battery than L7.

Copyright statement