

Grade 10 Students' Idea about the Direction of a Galvanometer's Needle due to the Flow of Current in a Simple DC Circuit

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Abstract

A galvanometer is always used to demonstrate the existence of (a conventional) current in a direct current (DC) circuit. The initial position of a galvanometer's needle is at the center when no current is applied. The galvanometer's needle could move either left or right from the center, labeled as negative and positive respectively, to indicate the direction of the current. However, during hands-on, researchers found students' misconceptions of the circuit connection and the relation between the direction of the galvanometer's needle and those of a current flow. Therefore, the aims of this study were to find 1) students' ideas about the direction of the galvanometer's needle in the two different circuit configurations and 2) students' conceptions of a DC circuit connection and current flow in a simple DC circuit. The participants, 93 Grade 10 students, were asked to respond to the two two-tier questions; the needle's direction of a galvanometer that connected in two different circuit connections with one resistor and one 9V battery. The first-tier responses presented students' ideas about the direction of the galvanometer's needle. The second-tier responses were students' reasons to support their first-tier responses that was used to analyze students' conceptions of a DC circuit connection and current flow. Results revealed that 1) almost all students were not able to identify the direction of the galvanometer's needle in the simple DC circuits correctly 2) Most students believed the galvanometer's needle did not move because of the wrong connection between the battery and galvanometer. Even though there was no broken part of the circuit, some students in this group gave the reason as the current cannot flow or there is no current as it happens when the circuit is open, and 3) some students had misconceptions about the resistor and current relation.

Keywords: Simple DC circuit, Electric Current, Galvanometer

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ความคิดของนักเรียนชั้นมัธยมศึกษาปีที่ 4 เกี่ยวกับทิศทางของเข็มของแกลแวนอมิเตอร์เนื่องจากการไหลของกระแสไฟฟ้าในวงจรไฟฟ้ากระแสตรงอย่างง่าย

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บทคัดย่อ

แกลแวนอมิเตอร์มักถูกนำมาใช้เพื่อแสดงให้เห็นถึงการมีอยู่ของกระแสไฟฟ้าในวงจรไฟฟ้ากระแสตรง (DC) เมื่อไม่มีกระแสไฟฟ้าไหลผ่านเข็มของแกลแวนอมิเตอร์จะอยู่ตรงกลางซึ่งเป็นตำแหน่งเริ่มต้น เข็มของแกลแวนอมิเตอร์สามารถเคลื่อนไปทางซ้ายหรือขวาจากตำแหน่งเริ่มต้น เพื่อระบุทิศทางของกระแสไฟฟ้าว่าเป็นค่าลบหรือค่าบวกตามลำดับ อย่างไรก็ตาม ในระหว่างการลงมือปฏิบัติ นักวิจัยพบว่านักเรียนบางคนสับสนกับการต่อวงจรและความสัมพันธ์ระหว่างทิศทางของเข็มแกลแวนอมิเตอร์กับทิศทางของกระแส ดังนั้นจุดมุ่งหมายของการศึกษาคั้งนี้ คือ การค้นหา

- 1) ความคิดของนักเรียนเกี่ยวกับทิศทางของเข็มแกลแวนอมิเตอร์ในวงจรสองแบบที่มีการต่อวงจรแตกต่างกัน และ
- 2) มโนทัศน์ของนักเรียนเกี่ยวกับการต่ออุปกรณ์ต่าง ๆ ในวงจรกระแสตรงและกระแสไฟในวงจรไฟฟ้ากระแสตรงอย่างง่าย ผู้เข้าร่วมการวิจัย คือ นักเรียนชั้นมัธยมศึกษาปีที่ 4 จำนวน 93 คน ข้อคำถามที่ใช้ในการเก็บข้อมูลเป็นชนิดสองระดับจำนวน 2 ข้อ โดยคำถาม คือ ทิศทางของเข็มแกลแวนอมิเตอร์ที่ต่ออยู่กับตัวต้านทานหนึ่งตัวและแบตเตอรี่ 9V หนึ่งก้อนในวงจรที่แตกต่างกัน 2 วงจร คำตอบในระดับแรกของคำถาม แสดงถึงแนวคิดของนักเรียนเกี่ยวกับทิศทางของเข็มแกลแวนอมิเตอร์ในวงจรแบบต่าง ๆ คำตอบในระดับที่สองของคำถาม แสดงถึงเหตุผลของนักเรียนที่สนับสนุนคำตอบในระดับแรก ซึ่งผู้วิจัยใช้ในการวิเคราะห์แนวคิดของนักเรียนเกี่ยวกับการต่อวงจรไฟฟ้ากระแสตรง และการไหลของกระแสไฟฟ้า ผลการศึกษาพบว่า 1) นักศึกษาเกือบทั้งหมดไม่สามารถระบุทิศทางของเข็มแกลแวนอมิเตอร์ในวงจรไฟฟ้ากระแสตรงอย่างง่ายได้อย่างถูกต้อง 2) นักเรียนส่วนใหญ่เชื่อว่าเข็มของแกลแวนอมิเตอร์ไม่เคลื่อนที่เนื่องจากการเชื่อมต่อระหว่างแบตเตอรี่กับแกลแวนอมิเตอร์ไม่ถูกต้อง ถึงแม้ว่าวงจรไฟฟ้าในข้อคำถามจะเป็นวงจรปิด แต่นักศึกษาบางคนในกลุ่มนี้ก็ให้เหตุผลว่ากระแสไฟฟ้าไหลไม่ได้หรือไม่มีกระแส เหมือนที่เกิดขึ้นเมื่อวงจรเปิด และ
- 3) นักเรียนบางคนมีความเข้าใจผิดเกี่ยวกับความสัมพันธ์ระหว่างตัวต้านทานและกระแสไฟฟ้าที่ไหลในวงจร

คำสำคัญ: วงจรไฟฟ้ากระแสตรงอย่างง่าย, กระแสไฟฟ้า, แกลแวนอมิเตอร์

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Introduction

Simple DC circuit is one of the topics that the secondary school students around the world must learn and have learning difficulties (Burde, Weatherby, & Kronenberger, 2021; Burde & Wilhelm, 2020; Curriculum Planning and Development Division, 2013; Curriculum Planning and Development Division, 2012; Ivanjek et al., 2021; Khwanda & Kriek, 2020; The Ministry of Education Thailand, 2008; Yangon International School, 2016). Simple DC circuit consists of a DC current source connected to a load or loads. There are two types of connection: series and parallel that allow current flow from the source through the load(s) and back into the source as a loop. In a series circuit, current flows through a single path passing through each load. A series circuit will not function if one part of the circuit is broken (named as “open circuit”) because the current will not flow through the rest of the circuit (see figure 1). On the other hand, the current in a parallel circuit is divided into two or more paths (named as “branch current”), the magnitude of branch current(s) depends on the branch resistance(s), before recombining to complete the circuit. Therefore, if one part of the circuit is broken, the other parts is still functioning (see figure 2).

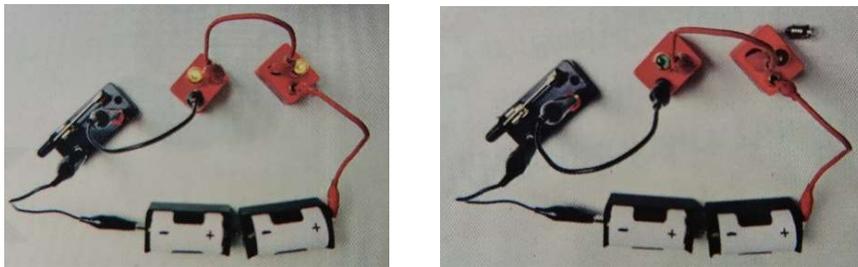


Figure 1. Series circuit (The Institute for the Promotion of Teaching Science and Technology (IPST), 2021a)

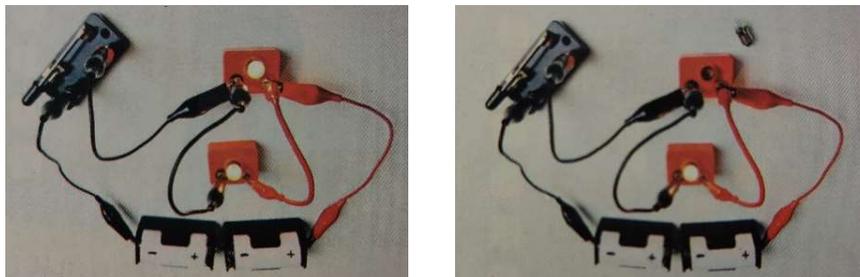


Figure 2. Parallel circuit (The Institute for the Promotion of Teaching Science and Technology (IPST), 2021a)

Electrical current is one of the main fundamental quantities in the topic of a simple DC circuit. Students must know 1) the meaning of current, a flow of electric charge or electric charge in motion, 2) the magnitude of current depends on the resistance and potential difference follow by the Ohm’s law, and 3) the direction of the current, flowing from positive to negative poles of the current source e.g., battery (see figure 3).

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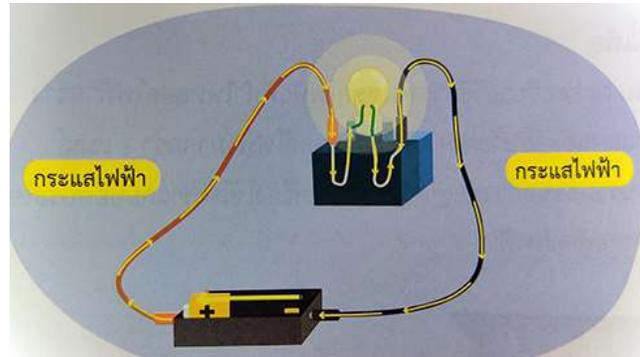


Figure 3. The picture in the Thai grade 6 standard science and technology textbook that presenting the current flow in a circuit (the yellow arrow). (The Institute for the Promotion of Teaching Science and Technology (IPST), 2021a)

In the class, teachers can either simply tell students or give them a chance to observe the magnitude and direction of current through hands-on activity or demonstration. A galvanometer has always been used as a teaching tool to indicate the direction and to measure the amount of small current in a DC circuit. The galvanometer (see figure 4) is constructed with a small pivoting coil, attached to a thin pointer that traverses a calibrated scale, of wire in the field of a permanent magnet and a tiny torsion spring to pull the coil and pointer to the zero position (middle area of the scale). The pointer can move to the left or right side of the zero position to indicate the direction of the current in the circuit (always named as negative or positive current) that is depending on a circuit configuration.



Figure 4. A galvanometer

As the galvanometer is used to display the direction of current flow in a DC circuit both for the hands-on laboratory or demonstration and the lack of research about students' ideas about the relation between the direction of the galvanometer's needle and those of a current flow. Therefore, this research aims to investigate students' ideas about the direction of the galvanometer's needle and students' conceptions of a DC circuit connection and current flow in a simple DC circuit.

Research Objectives

1. To investigate Thai students' ideas about the direction of the galvanometer's needle in the two different circuit configurations
2. To investigate Thai students' conceptions of a DC circuit connection and current flow in a simple DC circuit.

Literature Review

Many researchers have studied students' difficulties in learning a DC circuit such as Khwanda and Kriek (2020) analyzed students' written explanation to the questions that focused on the concepts of current, series and parallel circuits. The researchers reported that most of the pre-service students lacked the conceptual understanding of the concept of current and the difference between a series and a parallel circuit. Ivanjek et al. (2021) used 25 two-tier multiple-choice items with the middle-school students in Austria and Germany and found that the students had difficulties of the main concepts regarding simple electric circuits. The concepts were open and closed circuits, electric current, resistance, series and parallel circuits, and electrical voltage. For the students' difficulties of electrical voltage, the researchers narrowed down to five students' difficulties consisting of 1) Voltage depends on the distance from the battery, 2) Voltage is used up by the light bulb, 3) The lack of differentiation between the concept of voltage and the concept of current, 4) Voltage has a constant value, and 5) Confusion of series and parallel circuits. Bryan and Stuessy (2006) discovered the prospective elementary teachers' misconception during their unguided inquiry investigation activity and named the misconceptions as "Brightness Rules".

In the activity, the teachers were asked to determine and explain what would happen to the brightness of otherwise identical light bulbs in a DC circuit when progressively bulbs were (a) added in series, (b) added in parallel, and then to explain how the relative brightness of multiple bulbs could be determined when they were connected in combination circuits. The "Brightness Rules" consist of 1) The total 'brightness' available to the bulb or bulbs in a circuit is dependent on the power supply, 2) A single bulb will have all of the 'brightness' available to the circuit, 3) When additional bulbs are connected in series with one existing bulb, the 'brightness' of that single bulb becomes divided evenly among itself and each of the additional bulbs, 4) In a parallel arrangement, the total 'brightness' is divided evenly among each branch, regardless of the number of bulbs in that branch. (Note: An exception is that branches in a circuit arrangement comprising only parallel branches are treated as separate circuits, each getting all the 'brightness' supplied by the power supply.) Kucukozer and Kocakulah (2007) studied from many researchers and found that students' misconceptions of simple electric circuits are as follows: 1) Current is consumed by circuit components. 2) Current comes out from the (+) pole of the battery and enters to the bulb where the current is consumed to light the bulb which is not affected by the second wire connected between the bulb and (-) pole. 3) Current comes out from both poles of the battery and clashes in the bulb to light it. The information from these researchers revealed that any part of the simple DC circuit could make any level of student the misconceptions.

The reasons why students have many misconceptions about the flow of current in a circuit were reported by many researchers. For example, Nurmi and Jaakkola (2004) reported that many students in the traditional teaching class had many misconceptions about electricity because textual teaching material, application tasks or hands-on laboratory could not encourage students to change

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their preconceptions. Besides, the concept of electricity was quite complicating and very abstract to students since they could not see and touch electricity. This suggestion was similar to those of Ates (2005) and Ipek and Calik (2008), they found that students could not directly perceive the current flows through the resistors. Furthermore, Baser and Durmus (2010) found that students' misconceptions related to their ideas about particular situations and their fundamental beliefs about how the world works.

Methodology

Participants

The participants were Thai grade 10 sciences and mathematics program students (80 male and 13 female) from one big size school in Nakhon Pathom province. These participants participated in an extra school science activity that researchers provided one out of many scientific active learning activities to the participants. They were informed in writing about the purpose of the study and were free to opt-out. All participants agreed to use data for academic purpose.

Tool

As the works of literature (Ates, 2005; Ipek & Calik, 2008; Kucukozer & Kocakulah, 2007) mentioned about students' misconception of and difficulty to perceive the current flow, researchers created the two two-tier questions to collect students' conceptions of a DC circuit connection, current flow, and direction of the galvanometer's needle. To check content validity and to ensure that each question was properly constructed, the Item-Objective Congruence (IOC) index of the questions were verified by three independent experts who had a degree in Physics and experiences in the field of physics education for more than five years. Besides, one of them is working in promoting science and physics to secondary school students in the Institute for the Promotion of Teaching Science and Technology (IPST) for more than ten years. The IOC index was 1.0 for both questions but two experts suggested that details of the galvanometers' display such as the plus and minus signs should be clearly seen. After revising according to the experts' suggestion, the questions were "Which direction of the needle of a galvanometer, connected in two different circuit connections with one resistor and one 9V battery, will move to?" (see figure 5). The first tier was used to check students' ability to identify the direction of the galvanometer's needle in the simple DC circuits. The second tier was used to collect students' reason behind their responses to the first tier. It could help researchers investigate 1) students' difficulty in learning the direction of current flow in the simple DC circuit if a galvanometer was used in the hands-on activity and 2) students' understanding about DC circuit connection and how current flow in the circuit.

Implementation and analysis

Participants had approximately 10 minutes to respond the two two-tier questions. As this study not only focused on students' ability to correctly identify the direction of the galvanometer's needle in the simple DC circuits but also focused on the students' conceptions of the DC circuit connection and current flow in the circuit, the second-tier responses were not scoring but grouping and categorising. This analysis would help researchers understand students more about the possible causes of students' understanding.

1. From the circuit on the left-hand side, which direction will the needle move to?

A. Move to the **left** side

B. Not move

C. Move to the **right** side

Please write down a short description to support your answer

.....

.....

2. From the circuit on the left-hand side, which direction will the needle move to?

A. Move to the **left** side

B. Not move

C. Move to the **right** side

Please write down a short description to support your answer

.....

.....

Figure 5. The two-tier questions used in this research.

Results and Discussion

Table 1 presents the number of first-tier students' correct response. The results revealed that most students have difficulty correctly identifying the direction of a galvanometer's needle in the simple DC circuit. Only two students or 2.15% could identify the direction of the galvanometer's needle correctly for both questions. However, these students could not give the correct response to the second tier of both questions. One of them only mentioned the connection between a resistor and a battery terminal for both questions. The other confused about the direction of the current as he/she mentioned the flowing of current from positive to negative pole for the first question and negative to positive pole for the second question.

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Table 1 The no. of first-tier students' correct response

Question No.	No. of first-tier students' correct response	
	Students	%
1	23	24.73
2	9	9.68
Both	2	2.15

23 and 9 students could give the correct response for the first tier of the 1st and 2nd questions respectively, but none of them could give the correct response to the second tier.

Table 2 The first-tier students' response

First-tier response of the		No. of response	
1 st question	2 nd question	Students	%
Not move	Move left	7	7.53
Not move	Move right	33	35.48
Not move	Not move	6	6.45
Move left	Not move	19	20.43
Move right	Not move	19	20.43
Move right	Move right	2	2.15
Move left	Move right	5	5.38
Move right	Move left	2	2.15

Table 2 reveals that most students (78 students or 83.87%) thought the galvanometers' needle in either the 1st or 2nd question would not move. 40 and 38 students (43.01% and 40.86%) gave "Not move" as the response for the first and second questions, respectively. While 6 students answered "Not move" for both questions (see figure 6). Two students believed the needle would only move to the right-hand side. This might be because the needle of a typical analogue meter always moves to the right-hand side. Only 7 students thought that the needle could move to the left- and right-hand side depending on the circuit connection. Therefore, it can be implied that the students might not be easy to learn or accept the direction of current flow in the simple DC circuit if a galvanometer is used to show the current direction.

To know students' conceptions of a DC circuit connection and current flow in a simple DC circuit, the first-tier and corresponding second-tier response, the reasons to support their first-tier response, for the 1st and 2nd questions were grouped and presented in the Table 3 and 4, respectively.

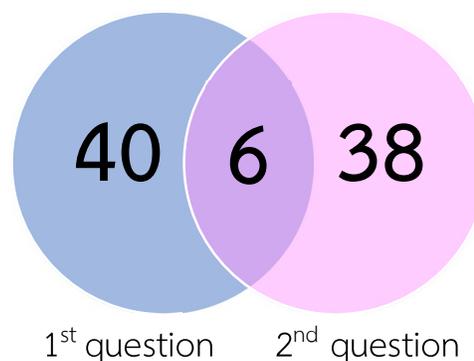


Figure 6. The number of students who's the first-tier response of the 1st and 2nd question was "Not move".

Table 3 presents the students' response of the 1st question. 46 students thought the galvanometer's needle would not move. 38 of them mentioned that it was because of a wrong circuit connection and explained that the correct circuit connection had to be the reverse polarity connection. 6 students gave the reason as the current cannot flow. One student had an idea, the negative current is equal to the positive current, that similar to the misconception reported by Kucukozer and Kocakulah (2007); current comes out from both poles of the battery and clashes in the bulb to light it.

24 students responded that the galvanometer's needle would move to the left-hand side. 4 of them mentioned that it was because of a correct circuit connection. 10 students of this group brought about the direction of the galvanometer's needle by the existing of the resistor at the right-hand side or the positive pole. For the concept of current flow, 2 students had a misconception that current flow from negative to positive poles of a battery, but the other 7 students had a correct conception that current flow from positive to negative poles of a battery.

23 students gave the correct response, the galvanometer's needle moves to the right-hand side. Only 7 of them gave the reason that current flow from positive to negative poles of a battery but did not mention about the circuit connection between a battery and a galvanometer. 5 students related the direction of the galvanometer's needle with the position of the resistor in the circuit. 6 students mentioned that the circuit connection was correct and explained that the connection between a galvanometer and a battery had to be same polarity connection.

Table 3. Students' response to the 1st questions (The correct response is indicated by **)

First-tier response	Group of second-tier response	No. of response
Move left	It is a correct connection.	4
	Current flow from negative to positive poles.	2
	Current flow from positive to negative poles.	7
	Negative charges move easier than positive charges because of a resistor at the positive pole.	4
	There is a resistor at the right-hand side.	6
	Not giving a reason	1
Move right*	It is a correct connection.	6
	Current flow from negative to positive poles.	1
	Current flow from positive to negative poles.	7
	The negative charge is greater than the positive charge, so the needle is repulsed to the positive side.	1
	The needle is pulled by the positive charge force.	1
	There is a resistor at the right-hand side.	5
	It is an Ohm's law.	1
	Not giving a reason	1
Not Move	It is a wrong connection.	38
	Current cannot flow.	6
	The negative current is equal to the positive current.	1
	Not giving a reason	1

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Table 4 presents the students' response of the 2nd question. 44 students gave the response that the galvanometer's needle would not move. 37 of them mentioned that it was a wrong circuit connection and explained that the correct circuit connection had to be the same polarity connection. 2 students mentioned that there was no current (flow in the circuit). One student had an idea that similar to the Coulomb's force, the battery- and galvanometer- poles are the opposite polarity that attract each other. Some students used 'Charge' rather than 'pole' when they mentioned to the polarity.

Table 4. Students' response to the 2nd questions (The correct response is indicated by **)

First-tier response	Group of second-tier response	No. of response
Move left*	It is a correct connection.	1
	Current flow from positive to negative poles.	2
	There is a resistor at the right-hand side.	6
Move right	It is a correct connection.	13
	Current flow from negative to positive poles.	1
	Current flow from positive to negative poles.	20
	There is a resistor at the right-hand side.	1
	It is an Ohm's law.	2
	The needle moves to the right-hand side.	1
	Not giving a reason	2
Not Move	It is a wrong connection.	37
	There is no current.	2
	The negative current is equal to the positive current.	1
	The battery- and galvanometer- poles are the opposite polarity that attract each other.	1
	There is nothing to measure.	1
	Not giving a reason	2

40 students responded that the galvanometer's needle would move to the right-hand side. 13 of them mentioned that it was a correct circuit connection and explained that the correct circuit connection had to be the reverse polarity connection. For the concept of current flow, one student had a misconception that current flow from negative to positive poles of a battery, but the other 20 students had a correct understanding that current flow from positive to negative poles of a battery. A few students gave the Ohm's law as a reason. One student believed the needle move to the right-hand side.

9 students gave the correct response, the galvanometer's needle moves to the left-hand side. Only 2 of them gave the reason that current flow from positive to negative poles of a battery without the circuit connection between a battery and a galvanometer mentioning. 6 students related the direction of the galvanometer's needle with the position of the resistor at the right-hand side of the circuit. One student thought that the connection between a galvanometer and a battery had to be reverse polarity connection.

In addition, some students' reason related to current direction and electric charge were found such as 1) The needle moved in the same direction as those of current. 2) Current decreasing because of passing through a resistor. 3) Negative charges were easier to move than positive charges because of a resistor. 4) The needle was attracted by the positive charge, and 5) The needle was repulsed by the negative charge.

In summary, students' response to the second tier of both questions could be categorized as related to 1) circuit connection between a galvanometer and a battery that was either the same or reverse polarity connection, 2) direction of current that flowed from both poles of a battery as reported by Kucukozer and Kocakulah (2007) or negative to positive pole or vice versa, and 3) the effect of a resistor to the direction of the current as reported by Ipek and Calik (2008) that students could not directly perceive the current flows through the resistors, some students thought that the galvanometers' needle move to the resistors' opposite side. Students had been learned these topics since they were grade 6 and grade 9 students but in the different context such as the battery-light bulb circuit connection and measuring an amount of current with an ammeter (see figure 7 and 8). The results show that students' prior knowledge such as 1) The battery-meter connection had to be the same polarity connection, and 2) The correct circuit connection had to be the different polarity connection effect to what students will learn. Therefore, the students' prior knowledge should be considered before developing an effective hands-on or demonstration active learning activity for students.



Figure 7 The picture in the Thai grade 9 standard science and technology textbook that presenting the measuring of an amount of current flow in a circuit with an ammeter. Students will learn that the battery-ammeter connection had to be the same polarity connection. (The Institute for the Promotion of Teaching Science and Technology (IPST), 2021b)

เขียนเครื่องหมาย ○ ล้อมรอบข้อที่ถูกต้องที่สุดเพียงข้อเดียว

จากภาพ ต้องต่อถ่านไฟฉายอย่างไร หลอดไฟฟ้าจึงสว่าง



Figure 8. The picture in the Thai grade 9 standard science and technology textbook that presenting the battery-light bulb circuit connection. Students will learn that the correct answer is the second circuit; the correct (battery) circuit connection had to be the different polarity connection. (The Institute for the Promotion of Teaching Science and Technology (IPST), 2021b)

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Suggestions for Further Research

As the number of participants in this research is very small to be a representative of Thai students but the students' misconceptions found in this research are agree with those of the previous research. However, more data collection is needed to create stronger conclusion. If the second-tier questions use to collect the data (see figure 5) are developed to the close-ended question (multiple choice), it will be easier to collect and analyze the data. On the other hand, if the display of the instrument that used to demonstrate the direction of current flow in a circuit is agree with students' expectation (as they have learned already), it will be easy for students to accept what they have learned about the current flow in a circuit. Therefore, the instrument is the other one consideration for further research.

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