The Predict-Observe-Explain technique as a tool for students' understanding of electric circuits

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This paper looks at the learning of the topic of electric circuits by 17-year-old students covering an advanced level course in physics, in Malta. Even if electric circuits are taught in schools both at primary and secondary level, many researchers have reported problems related to the understanding of circuits. The ideas presented during the teaching process are described as 'abstract' by students and the so-called 'simple circuit' is seen as anything but simple. This paper reports the results of a pilot study dealing with the learning of key concepts in electric circuits, focussing mainly on potential difference in simple parallel circuits. Students' understanding was probed using a pre-test and a post-test. Interviews were then conducted using the Predict-Observe-Explain technique to further probe understanding of parallel circuits. The study indicated that all the interviewees made a visible effort to try to correctly explain how the circuit presented to them works. Moreover, about one third of these students managed to bridge the gap between their unscientific intuitions and the scientific view. The Predict-Observe-Explain technique helped students shift their thinking towards the scientific view regarding parallel circuits. The implication is that teachers must not ignore simple but effective teaching techniques which focus on putting the responsibility of learning on the student. Choosing a teaching strategy which helps to arouse students' curiosity by creating cognitive conflicts to make students think, leads the way to a powerful and a qualitatively enriched teaching and learning experience.

Keywords: The Predict-Observe-Explain technique; active learning; thinking for learning; electric circuits.

Introduction

Teachers teach and expect students to learn. Teachers try to use pedagogies that motivate their students towards meaningful learning. This paper emphasizes the idea that unless the teacher as the expert uses methods that make students aware of their responsibility for learning, then it is difficult for students to understand key concepts.

A study conducted with Maltese students at post-secondary level, as they cover the topic of electric circuits, is described. Students hear and deal with ideas related to electric circuits before they start attending school. Moreover, the topic is one which is taught in schools at both primary and secondary levels. Yet, most students still find this topic difficult and abstract. They do not see what is happening inside the circuit wires when a potential difference is applied across two points. By testing students before and after a course of study following traditional teaching methods, students' ideas were probed, gauging students' understanding. Students' ideas were further probed, as they were developing, by conducting semi-structured interviews using the Predict-Observe-Explain (POE) technique [1] – a technique which helped elicit students' intuitive ideas in prediction before doing an experiment, and any changes in these ideas after doing the experiment. The results of the study are discussed to show the effectiveness of simple techniques, in this case the POE technique, which can be used in the classroom in an effort to make the teaching-learning process more fruitful.

Background

During these last 30 years, many researchers have shown interest and reported results of studies related to students' understanding of electric circuits (see, for example, [2]). Students of different ages have been shown to hold alternative views of how a circuit functions.

A main problem is that students tend to use different mental models to explain the flow of an electric current [3, 4]. Millar and King [5] say that 'one consistent finding reported by researchers is that students tend to reason 'locally' or 'sequentially' about the effects of changes in an electric circuit. If a variable resistor is altered, students predict changes in meter readings 'after' the resistor but not 'before'; a change at one point in a circuit is not necessarily seen as causing changes elsewhere in the circuit' (p. 340). Liegeois [6] also emphasises that students often find it very difficult to look at the electric circuit as one whole system.

The idea of potential difference (p.d.) also seems to pose difficulty for understanding. Duit and von Rhöneck [7] indicate that before instruction, some students relate p.d. to 'strength of a battery' or 'intensity of force of the current'. These authors say that, even after instruction, students use the p.d. concept in a way which shows that they believe that it has the same properties as the current concept. This idea is also supported by Eylon and Ganiel [8] who say that students tend to be 'current minded' rather than 'voltage minded', thereby confusing cause and effect, even in simple circuits.

Students have also been found to experience difficulty in the translation of a circuit diagram into practice [9]. Moreover, retention of scientific views after instruction does not last for long with many students. If students do not understand what they are taught, they easily go back to intuitive ideas which make more sense to them [10 - 12].

Aims and Framework

This paper reports the results of a pilot study dealing with the learning of key concepts in electricity, putting a focus on the understanding of potential difference in simple parallel circuits. Vygotsky's theory of learning and development [13] forms the framework for this study. Vygotsky points to the necessity of adult intervention to promote children's learning. Vygotsky [14] refers to the zone of proximal development as '….the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (p.86). Teaching within this zone is said to help develop students' ideas and foster intellectual growth. It is within this framework that the present study looks into how traditional instruction affects learning and what can make a contribution towards better understanding of ideas related to electric circuits.

The research questions asked were:

• By how far, does traditional instruction help students to progress in their ideas on electric circuits?

• Can an intervention using the Predict-Observe-Explain (POE) technique, help students improve their understanding of electric circuits? If yes, in what way does the POE technique help?

Method and sample

Before instruction in the topic, a group of 61 students in their second year of study at a post-secondary college in Malta were asked to answer some multiple choice questions on basic ideas about simple electric circuits. This constituted the pre-test. At this time, students' knowledge of the topic was based on the ideas which they had retained from their study at secondary level, one year earlier. The study of electric circuits was not part of the syllabus covered by the students during their first year at the college.

Students then attended 2 one hour lectures on electric circuits per week, for two months. They also attended a one hour tutorial a week, helping them sort out difficulties with qualitative and quantitative questions on the topic. Students also attended a 2-hour practical session per week, learning to handle apparatus and do experiments using electric circuits. At the end of the course, the same students sat a post-test. The post-test consisted of some questions on the pre-test which students had found difficult to answer, together with questions based on material covered during the course of study, focussing mainly on ideas related to the understanding of electric potential difference. A question asked in both pre- and post-test, consisted of the two-tier question shown in the next section, based on the circuit in Figure 1. The results of the post-test, and observed students' progress through class discussions, helped in making decisions about students of different ability who would be asked to participate in interviews. Nineteen students from the sample group took part in semi-structured interviews using the POE technique. Students worked hands-on with the circuit, as they were guided and asked questions by the teacher/researcher. Using the POE technique meant that *students were first asked to predict what happens to the ammeter reading once the switch S was closed, giving reasons for their predictions*. Then the experiment was done, with the students being allowed to handle the apparatus. *The result was observed and students had to explain any discrepancies between their predictions and the results, if any existed, once again giving reasons for their explanations.* During this interview, the students' understanding of parallel circuits was thus probed.

Students were interviewed in groups of no more than four students per group, according to their availability during a school day. This study was part of a larger piece of research work and at this stage I was interested in observing the dynamics of peer interaction. The interviews were audio taped and transcripts were then prepared.

The circuit used and questions asked

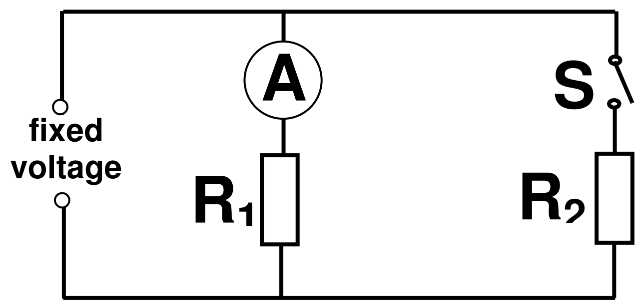

Figure 1. The circuit used

In this circuit, two resistors, R_1 and R_2 are connected in parallel to a power supply.
The power supply has a fixed voltage output.
The switch S is open.
There is a reading on the ammeter.
The switch **<u>is then closed</u>**.

(a) What happens to the reading on the ammeter? Choose one answer.
 (i) It gets bigger.
 (ii) It stays the same.
 (iii) It gets smaller.

(b) How would you explain this? Choose one answer.
 (i) Some of the current now goes through R_2, bypassing R_1.
 (ii) Two resistors need a bigger current from the power supply.
 (iii) The voltage across each parallel branch stays the same.
 (iv) The total R is now bigger, so the current gets less.
 (v) Other (Please explain your answer). (Source: [15])

Results

The following are the pre-test results for the whole group of 61 students as they answered the questions posed related to the circuit diagram shown above.

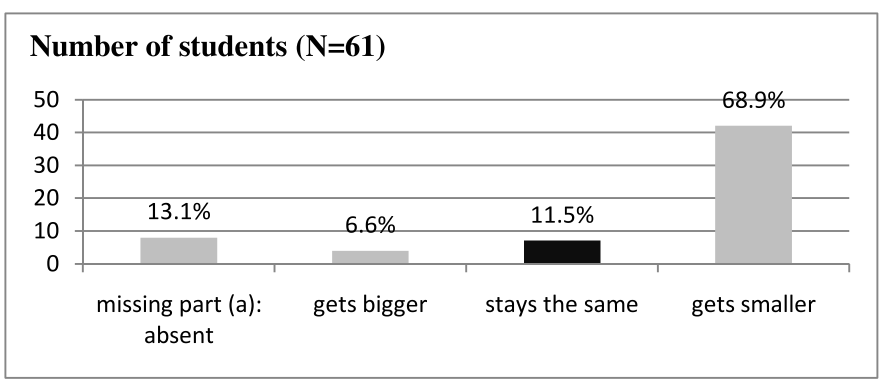

Figure 2. What does the ammeter read when the switch is closed?

Only 11.5 % of the students answered correctly to part (a) of the question, saying that the ammeter reading remains the same. The majority of the students (68.9%) said that the reading on the ammeter would be smaller. Students have a correct idea that the current splits at the junction between the two resistors once the second resistor R_2 is in the circuit, but this idea is so predominant that students do not 'see' that the potential difference across the resistance R_1 must remain the same, since this is still connected directly across the battery and that, therefore, the same current as before must pass through R_1.

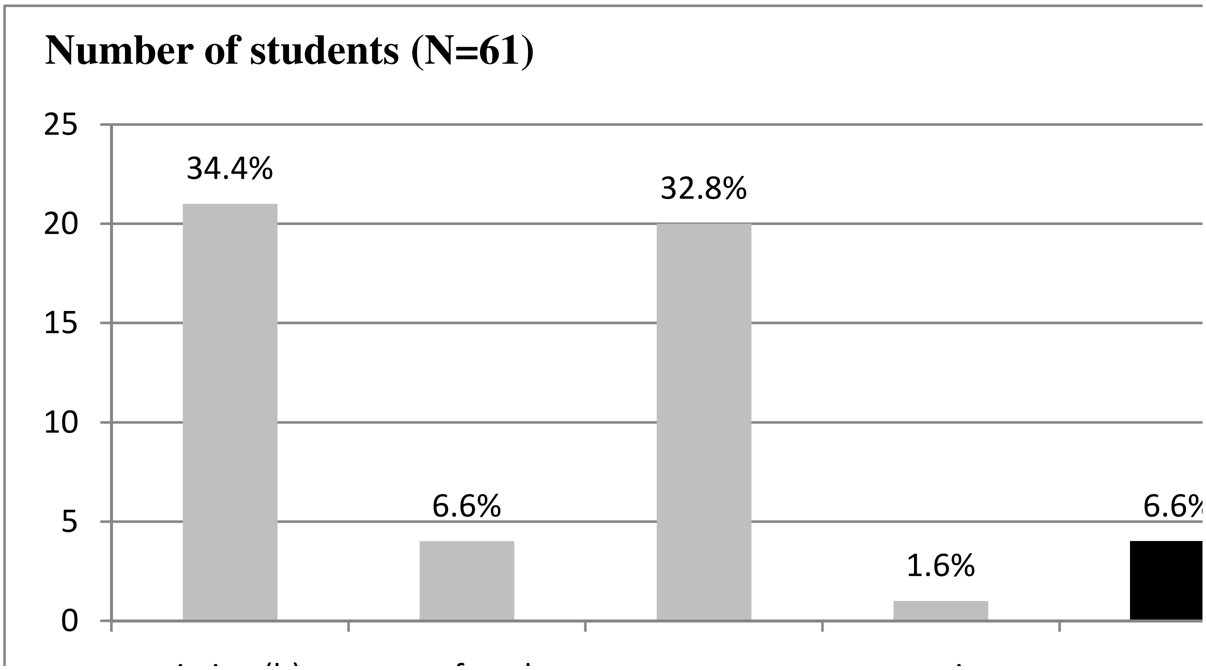

Figure 3. Pre-test justifications given for the change in current when the switch is closed

In the second part of the question, where students were meant to explain the answer they gave to part (a), only 6.6% of the students chose the correct reason. Some of these students had not even chosen the correct response to part (a). A good number of students opted not to answer this question (34.4%), and 32.8% were showing that their concern was to consider the current passing through the second resistor introduced in the circuit, without much thought about the potential difference across the resistors.

The results in Table 1 below, show at a glance which combinations of answers were preferred by the students. Quite a large number of students thought that the ammeter shows a lower reading because some current now passes through R_2 when the latter forms part of the circuit. A good number of students thought that the ammeter shows a smaller value because the total resistance in the circuit increases. It seems that these students were applying the principles of series circuits erroneously to parallel circuits, and concluding that adding a resistor in parallel increases the total resistance of the circuit. Only two students gave the correct answer to part (b), coupled with the correct reason in part (b).

Table 1. Cross-tabulation of results (Note: 8 students were absent for the pre-test)

Answer to part (a)	Reason for answer to part (a)						TOTAL
	no answer	(i) some current through R_2	(ii) two resistors need more current	**(iii) same voltage across parallel branch**	**(iv) R (total) is now bigger, so current is less**	(v) confused others	
(i) becomes bigger	1	-	-	1	1	1	4
(ii) remains the same	3	1	1	**2**	-	-	7
(iii) becomes smaller	9	**19**	-	1	**10**	3	42
TOTAL	13	20	1	4	11	4	53

The answers from the students who were interviewed

The results of the post-test and the interview using the POE technique

Table 2. The results of the post-test and the subsequent interview

Student Code	Post-test / 18	Interview: predictions before observation				Interview: General comments on students' responses after observation
		I less	I more	I same	I changes	
A	9			x		Correct conception from the start
B	10		x			R_{total} ↓, so I ↑; disregards experimental evidence
C	10	x				Persistent confusion
D	8				R_{total} changes	Reaches correct conception
E	5		x			R_{total} ↓, so I ↑; disregards experimental evidence
F	14		x			Reaches correct conception
G	8				I splits up	Persistent confusion; thinks the ammeter has problems
H	5	x				Persistent confusion; puts the blame on bad teaching
I	5	x				Reaches correct conception
J	16	x				Persistent confusion
K	15	x				Reaches correct conception
L	12	x				Disregards experimental evidence
M	16	x				Reaches correct conception
N	17	x				Reaches correct conception
O	6	x				Persistent confusion
P	12	x				Reaches correct conception
Q	10	x				Persistent confusion
R	12	x				Persistent confusion
S	4			x		Persistent confusion

Table 3. Some general observations from the interview transcripts

Prediction			Explanation after observation					
I subdivides	R_{total} is mentioned	Give correct solution before	Mentions problems with circuit	$R_1=R_2$	Students say that $R_2= 0$	Students say R_2 is too large	Back and forth ideas	Reaches correct conception in terms of p.d.
8	3	1	1	1	1	1	2	8

The results in Tables 2 and 3 show that most of the students' first reactions to the question, *in prediction*, after instruction and independent of their test performance, were to say that the ammeter reads a smaller current value. This was much the same result as in the pre-test, showing that students hold on strongly to their intuitive ideas, applying them consistently. For most students, assuming a constant power supply in use, it is the current supplied which remains the same and not necessarily the potential difference across the supply and the components connected in parallel to it. Moreover, although students saw the ammeter, yet the position where it was connected did not seem to be an important detail for them. *After observing* the change in the circuit and the result of that change, 37% of the students resolved the conflicts which were created, and gave the correct reason to support the result. Others were, however, still confused, offering no real or correct explanation, even after instruction. Some even kept defending their erroneous conclusions. Student H, for example, put the blame of his confusion on bad teaching. Student G thought that perhaps his answer was different from the result of the experiment because the ammeter was not functioning well.

On the other hand, the general observations of the interview transcripts in Table 3 show at a glance that the students who still looked at the current immediately in prediction (saying, 'I subdivides'), outnumbered those who looked at what was happening to the resistance in the circuit (mentioning R_{total}). Moreover, considering those who finally gave the correct explanation after observation, it seems that students did start to note the potential difference effects, but only after they had observed the result of the experiment.

In as far as the student-student interaction, this seemed to have helped to make students more motivated to think and revise their ideas during the interview, in order to understand why the circuit was behaving that way. This positive interaction between students helped to indicate the possibility of using the POE technique on a class-wide scale to structure and guide students' discussions.

Discussion

Confirmation of the literature

One of the main aims for conducting the above study was to see by how far instruction had helped students to progress in their learning of this topic. The results from the pre-test indicate that the instruction students had had at secondary level had not helped much. Moreover, students still found difficulty with key ideas related to parallel electric circuits even after these had been addressed in detail by instruction at advanced level.

The answers provided by the student sample in this study confirmed problems in understanding circuits and learning in general which had been pointed at by previous studies. Some students seemed to have looked at the number of resistances in the circuit and not on the circuit configuration [16]. Students 'saw' the same current coming from the same power supply, even when another resistance was added. It seemed that students saw the splitting of current at the junction, but it was the same current as with one resistor in the circuit that they were imagining was passing through the main circuit [16, 17]. Difficulty and confusion were especially evident when students were asked to explain their observations.

Moreover, even after instruction, students held on strongly to their intuitive ideas. White and Gunstone [1] also refer to this common position taken by students. These authors describe an experiment done with their students, with the latter predicting that a bucket would move as a result of changes made to the conditions of the experiment. Even when the bucket did not move, intuitions were held so strongly that some students actually continued to back their argument by saying: '…the bucket moved so little that I could not actually see it!' ([1], p. 51). This was very similar to what students G and H had done (see Table 2). As Schlichting, (cited in [7]), has observed students just 'see' what their conceptions allow them to see.

The use of the Predict-Observe-Explain (POE) technique

The POE technique is a good probe for understanding [1, 18]. This study supports the use of the POE technique as a tool to promote students' understanding of electric circuits. Had students' initial response in prediction been taken as their final answer, then some students' ability to develop their understanding of the topic would have been undermined.

The use of the POE technique through the interviews helped some students to grasp the ideas of why the circuit worked the way it did. This pointed towards the importance of having students deal with simple experiments while being asked for predictions with reason, of what is expected to happen, allowing time for ideas to sink in and to develop, reinforcing deeper understanding. The POE task also helped to motivate students to search for a valid reason for why things may not have resulted as predicted. The idea of using these tasks in teaching, helping students to distinguish between their intuitive ideas and the scientific ones, can be an effective way of tutoring students. Students in this study started with their intuitive ideas and were given the space to work on these ideas, clarify their views and develop concepts. Moreover, students' misconceptions were being addressed there and then. This is an important aspect of teaching and learning. It is evident that making students just recall the facts is not enough to motivate them to learn and understand. Students may be externally motivated to recall facts, relying on memory work even if they find that the material has not been understood. Students may find that they still pass exams this way, but once the exam is over, all is easily forgotten. Rosenthal and Henderson [19] likewise stress that "as usual, only telling students has limited effect; they (the students) must struggle with…. problems on their own or in small groups" (p. 324). True educators should look for ways which make learning last.

Furthermore, this study indicates how by making use of the POE technique, teachers can teach more effectively. POEs can help the teacher to better gauge students' understanding and thus plan lessons that are based on what students already know. Teachers can use the POE technique to induce students to take more responsibility for their learning by having students participate more actively in it.

In this study, the interviews were conducted with a small group of students. However, the POE technique can be scaled up to being used with a whole class. An experimental set-up can be shown to students, or one may even resort to multimedia. Students may then be asked to write down their predictions with reasons of what they expect to happen during the experiment. A discussion can then follow to expose students to the various views from different students. After observing the experiment, some time can be given to students to reflect on why the experiment worked out that way. Reflection can be undertaken either individually, or with students discussing ideas in small groups. A brief teacher guided discussion can then follow, directing ideas towards scientific views. The technique being suggested is similar to the style of presentation used during interactive lecture demonstrations. The latter have been reported to help students' understanding [20].

Having said all this, one must admit that with the claim from teachers that they cannot keep adding more to what they have to do in class, over and above an already overloaded curriculum, the suggestion to introducing the POE technique as a tool to help learning *may* at first appear as an extra burden to carry. Yet, this teaching method, if utilized carefully, only poses a *small* change to a usual lesson plan. Even so, as Viennot [21] says, the 'so-called 'small' changes can do more than commonly expected' (p. 15).

Conclusion

More research guiding us towards the knowledge of how students develop their ideas is required. The findings from such research can better guide us towards making the best use of the right teaching methods. As this study has indicated, the POE technique can help, but which experiment is more appropriate, when is it best to use it, and with whom? All these questions can be answered with the help of further research related to the topic. The POE technique can be used to give that slight *twist* to our teaching, making it more effective. This study has shown that POEs can help students' learning about electric circuits, yet this method may be applied in other topics and other subjects too. The idea is to guide students to take 'active steps to manage their own learning processes to facilitate knowledge acquisition and comprehension' ([22], p. 243). This is when true learning takes place. The emphasis must be on the importance of using teaching methods, which like the POE technique, provide for active learning, offering the key to a powerful and qualitatively enriched teaching and learning experience.

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