IMPACT: International Journal of Research in Humanities, Arts and Literature (IMPACT: IJRHAL)
ISSN (P): 2347–4564; ISSN (E): 2321–8878
Vol. 7, Issue 1, Jan 2019, 563–570

AN INQUIRY INTO STUDENTS' UNDERSTANDING OF ELECTRIC CIRCUITS

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Received: 07 Jan 2019 **Accepted:** 19 Jan 2019 **Published:** 25 Jan 2019

ABSTRACT

Students' alternate conceptions had been area of interest and extensive research in Science Education in the last three decades. 'Electricity' is one of the difficult topic in physics and a lot research has been done to explore students' mental models to explain the concepts in electricity. This study explores middle school and secondary school students' understanding about electric circuits and alternate conceptions held by them. The study also unearths various mental models subscribed by the students in their understanding of simple electric circuits. The study also explores the gender differences in the alternate conceptions of middle and secondary school students.

KEYWORDS: *Alternate Conceptions, Electric Circuits, Mental Models*

INTRODUCTION

Students' alternate conceptions and misconceptions in science has been a central issue in the research in the area of science education These studies indicated that learners' prior knowledge due to their experiences about many science topics are often in conflict with scientific knowledge(R.Driver1986, Duit and Miller2002,Osborne1985). As these ideas are resistant to change, they pose challenge to teachers and curriculum developers and act as barriers to conceptual learning and scientific understanding. The gap between every day concepts and scientific concepts lead to underachievement , disinterest and lack of motivation in science. These also make Science more abstract and unreal to the students, discouraging to pursue sciences. The topic 'Electricity' is often perceived as a difficult and abstract topic in Physics. Research done in this area reveals that students in all the age groups not only have conceptual difficulties but also strong alternate conceptions(Shipstone 1988, Osborne 1986, Chang and Chen 1998, Kucukozer 2007).As students use and also are aware of lot of electrical and electronic appliances in their daily life, these everyday experiences shape up their understanding and contribute towards development of many alternate conceptions and mis conceptions in this topic . Students use many mental models to explain the electric circuits (Shipstone 1988, Osborne 1984) and these are often incomplete and in conflict with scientific explanations of electrical circuits (Lee 2001). Hence difficulties in understanding concepts in electricity partly arise from this inconsistency between students' mental representations and the scientific knowledge which they encounter in the formal curriculum. Literature review reveals that some of the pre dominant models contributing to alternate conceptions in electricity are "attenuation modelsharing model, clashing current model, unipolar model"(Shipstone 1988, Chambers and Andre 1997) , 'Sequential model"(Dupin and Joshua 1987, Shipstone 1988),"empirical rule model"(Heller and Finley 1992), "local reasoning model"(Cohen 1988) etc. Apart from these, terminology used (power, energy , flow etc) , cognitive readiness, textbooks, language, socio cultural experiences , teacher's beliefs and pedagogy etc contribute to the development of alternate conceptions regarding electric circuits in the

learners. However there is no consensus regarding the impact of gender. Some researchstudies have shown strong correlation between gender and misconceptions and that girls have more misconceptions in electric circuits than boys(Sencarand Eryilmaz,2003,Engelhardt 2004, Pardhan and Bano 2001) whereas other researches contradict this (Anamuah et al 2001)

This paper presentsthe Middle and Secondary school students' understanding of basic electric circuits and analyses the alternate conceptions held by the students in this area. The study also explores the effect of gender on understanding of electric circuits.

METHODOLOGY

This paper is a part of large study conducted to find out alternate conceptions of the middle and secondary school students in various concepts of physics. However this paper focusses on analysis of students' understanding of basic electric circuits. The sample consists of 400 middle school students(age 11-13 years) and 400 secondary schoolstudentsage 14-16 years) studying in various Government aided schools in Delhi. The sample is convenient as only those schools and students who were willing to participate voluntarily in the study were chosen. Alsoonly Government aided schools were chosen to minimize the effect of socio cultural experiences on the conceptions held by the student. Altough the actual sample was more than 400 in each case.Only those who attempted all questions in thethis topic were considered for analysis. The tools consist of written diagnostic questionnaire constructed on the basis of detailed review of literature on the alternate conceptions of students in electricity. Altough the questions were in the form of multiple choice,the distractors were provided in terms of already existing misconceptions as revealed by literature review. The questions were also followed by reason for choosing a particular option in order to capture their thinking process. The responses were analysed quantitatively and qualitatively using descriptive and inferential statistics.

DISCUSSION

The analysis of responses is done for identification of mis conceptions and also under which category of mental models of electricity they fall.

Understanding about Battery as a Source of Electricity(Source -Consumer Model)

Many researches in the area of alternative conceptions of children in the electric circuits focused on students' conceptualization of battery as a source of electricity or electrical energy. When asked why battery is considered as source of electricity, 67% of middle school students responded that battery is a store house of electrons, which flow through the wire from one terminal to another. Only 14% gave nearly correct response that battery provides the energy for electrons in the wire to move.Altough this mis conception decreased in secondary school students as 37% students still hold to the understanding that battery is a store house of electrons. This kind of alternate conceptions was typically referred as 'Source -Consumer Model" (Shipstone1988) in which students have an underlying idea that there is a necessity of source(battery in this case) and a consumer (bulb, electrical appliance etc) . In such conceptions of students, a battery is seen as an "active agent" or 'giver" of electricity,energy , power etc and a bulb or any other appliance is a receiver or "sink"(Shipstone D)

Conceptual Mental Models for Current Flow in Circuits

Literature review reveals that in order to explain their the conceptualization of Source Consumer model, students across age groups follow various mental models. Osborne (1985) has categorizedthese mental models into four types.

- The unipolar Model (Ref 1 , Fig 1)-In this type of mental model, it is assumed that there is no current in the return path and only one terminal of battery and one wire is sufficient.
- The clashing Current Model(Ref 2, Fig 1) In this , it is assumed that current flows from both terminals of the battery and two wires are needed and current flows from both to the bulb
- The attenuation Model- In this model of understanding, current flows around the circuit in one direction and a part of current is used up by the bulb in lighting up . Hence the current leaving is less than current entering the bulb.
- The sharing model- In this, when there are more than one bulb, current is shared between them and current is not conserved.

In order to explore students' understanding about the source -consumer model of simple electric circuit, following question representing various models was asked

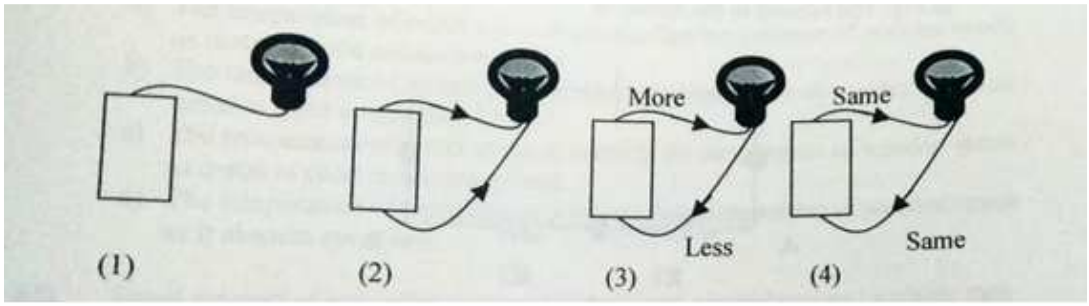

Figure 1

The responses are categorized into the models represented in the following table (1)

Table 1

S. No.	Model of Alternate Conceptions	Middle School Students			Secondary School students		
		Girls(%)	Boys(%)	Total(%)	Girls(%)	Boys(%)	Total (%)
1	Unipolar Model(1, Fig 1)	8.5%	5%	7%	Nil	nil	-0
2	Clashing current model (2, fig 1)	20%	22.5%	21%	14.5%	4%	9%
3	Attenuation Model(3, fig 1)	56%	52%	54%	41%	28%	34%
4	Scientific model (4, fig 1)	21.3%	15.7%	18%	64%*	51%	57%

*Significant at 0.05 Level

From the analysis of data, it is evident from the alternate conception of the attenuation model is pre dominant ie the mis conception that current entering the bulb is more than the current leaving indicating their belief that part of the current is "used up" by the bulb. The prelevance of this misconception has decreased in the secondary school students. The reason could be influence of formal instruction and curriculum as these topics are introduced in class VII, VIII and IX. There is a sharp increase in the scientific understanding of the flow of current in the circuit from middle school stage to secondary school stage. There is no major difference between alternate conceptions held by girls and boys in the middle

school stage but there is sharp difference at secondary stage(at 0.05 levelof significance). The probable reason could be influence of daily life experiences and contexts as generally adolescent boys are more interested in working with electric appliances and circuits at home as compared to girls.Also the interest towards engineering related careers start taking shape at this stage and may have influenced their thinking and conceptions.However,as this angle is not probed further, the observations cannot be generalized.

Understanding of Sequence Model

The next set of questions probed on extension of above models to sequence circuits ie one or more circuit elements (like bulb, resistor etc) are arranged These questions(Fig 2 and Fig 3) also probed if students have grasped the concept of conservation of current in a sequenced circuit

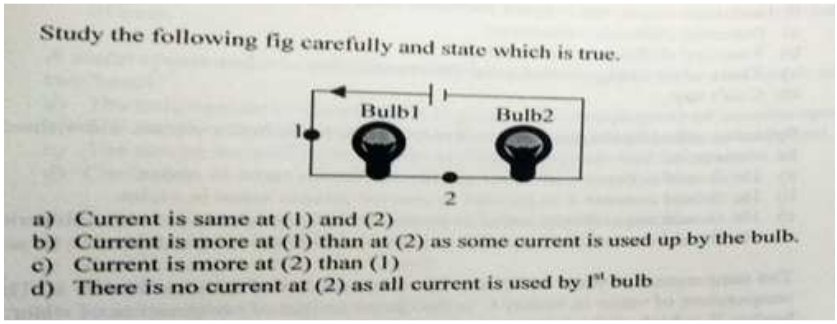

Figure 2

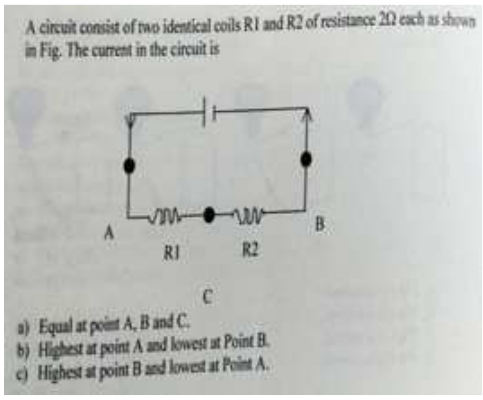

Figure 3

Analysis of responses shows that majority of students at middle school subscribed to attenuation model(71%) . Here options (b), (c) and (d) fall under attenuation model and sharing model. The students used attenuationmodel to show that some current is used by bulb and sharing model to explain flow of current to subsequent bulbs. However this mis conception decreased in the students of secondary school as 59% of students were able to give correct scientific explanation based on their understanding of conservation of electric current. The same situation was depicted in another question by using resistors instead of bulbs to probe their understanding on the relation between current and resistance. Analysis of responses revealed that in this context also majority of students subscribed to attenuation model and sharing model revealing that misconception of current being used up is extended to resistors also. Majority of students in middle school used attenuation model as well as sharing model to express their understanding that current decreases subsequently across each resistors. However this alternate conception has decreased in secondary school students, but persistant to certain extent.

Table 2

S. No.	Model Used	Middle School Students	Secondary School Students
1	Only attenuation model	19%	7%
2	Both attenuation and sharing model	55%	34%
3	Scientific model	26%	59%

Understanding of Current in a Complex Circuit

In complex circuits ie circuits having two or more elements, the understanding of relationship between total resistance and current is very important and the fact that this relationship is independent of resistors. The following question probed student's understanding of these two rules. The question asked to find out the effect of increasing or decreasing of R1 and R2 on the brightness of bulb separately.

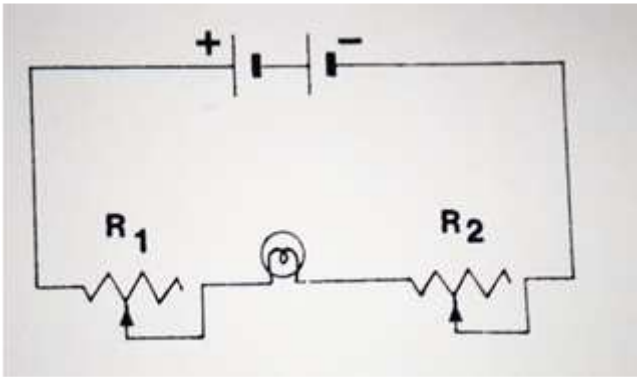

Figure 4

The predominant understanding which emerged from the analysis of responses is that the resistor placed before the bulb will only impact the brightness of bulb and the resistor placed after the bulb has on effect on the brightness of bulb. This has been referred as "Sequence model" in which spatial factors(position of bulb or resistor) plays an important role in childrens'understanding of circuits. This misconception is predominant both in secondary and middle school students.Subscribing to sequence model by students also results into failure of conservation of electric current.

The following table (Table no: 3) depicts the pre dominant alternate conceptions regarding electric circuits present in the middle school and secondary school students.

Table 3

Alternate Conceptions	Middle School Students (Age 12-13 Years)	Secondary School Students (14-16years)
A)Battery stores electrons	67%	43%
B) Connection to one terminal of bulb is sufficient	43%	12%
C)Current is used up by bulb	69%	37%
D)Current enters bulb from both the terminals of battery	58%	29%
E)Current entering circuit is more than current leaving the circuit	78%	59%
F)The amount of current entering each bulb or resistor placed in a circuit decreases subsequently	79%	53%
G)Position of resistor affects the brightness of bulb(current)	87%	62%

Impact of Gender on Understanding of Electric Circuits

Fig (5) represents the analysis of mis conceptions mentioned in the above table (Table no 3) stage wise in girls and boys separately.

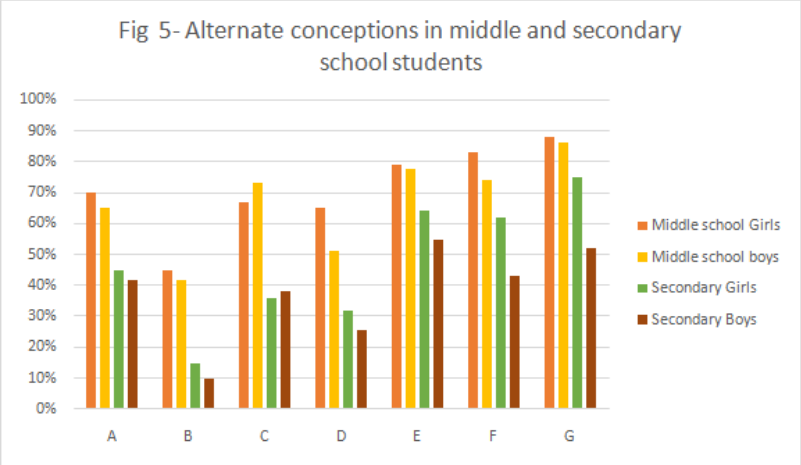

Figure 5: Alternate Conceptions in Middle and Secondary School Students.

The analysis also reveals that the misconceptions or alternative frameworks present in girls is more than boys and is significant (at 0.05 level of significance) at the secondary stage. There can be many reasons for this. One reason could be the influence of socialization and daily life experiences.The boys tend to tinker with electric circuits more than girls and this interest or habit is reinforced by socialization as often boys are asked and expected to fix up electricity related things at home. Also, they tend to see more gendered roles at home as usually electric fittings and repairs in general and on festivals like Diwali, Christmas are taken care by men of the family. Another reason could be that the career aspirations start taking place in the early adolescent years and boys tend to show more interest in electrical /electronics engineering and allied fields. This is also influenced greatly by social expectations and experiences.As the reasons for the gender differences in the responses is not probed in detail, these observations cannot be generalized.

CONCLUSIONS

Though this is not a large scale study, the sample size (total 800) is significant enough to arrive at an understanding of mental models subscribed by students in the concepts related to electric circuits. The alternate conceptions held by the students are in line with researches conducted across the world reinforcing the research finding that many mis- conceptions at a particular stage are present in students across the world. This study as well as other studies in the past have revealed that students' understanding in concepts related to "Electricity" especially electric circuits is different from scientific explanation. This poses additional challenge to the abstract nature of electricity. It is important for the teachers to know these prior ideas and address them in the classroom. It is also important to differentiate between electric current and electric energy as the students while using source consumer model equate current with energy. It is important to introduce the concept of electrical energy prior or simultaneously with electric current so that confusion of "used up" is reduced in this context. Variety of circuits needs to be explored and experimented so that students get ample opportunities to tinker around circuits and deduce the effects. Multiple modes of representation of concepts related to electric circuitslike graphic, diagrammatic and visual modes needs to be incorporated in the curriculum. ICT tools and virtual simulations can be used to supplement the classroom experiments to address and challenge alternate conceptions held by the students.

Another important conclusion is that the mis conceptions regarding electric circuits is more in girls than boys may be owing to the differences in social experiences and contexts. As more and more girls are encouraged for STEM related careers, it is important to address these mis conceptions in the classroom by providing more opportunities for experimentation. The gap of socialization experiences in the boys and girls can bridged by adopting gender sensitive pedagogy in the classroom. Further research is needed in this area to understand the reasons behind the gender differences in students' understanding of electric circuits.

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