A Study of Pre-service and In-Service Teachers' Understanding of Electrochemical Cells

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A survey of recent literature reveals that a good number of research reports/articles appeared in national and international journals on students' understanding of various science concepts. The researchers have evolved different terms to describe these understandings. Driver and Easley (1978) preferred to call them pre-conceptions; Gilbert, Osborne and Fensham (1982) used the term children's science; Cho, Kahle and Nordland (1985) evolved the term misconceptions; Driver and Erickson (1983) used the term alternative frameworks and Fischer and Lipson (1986) preferred to address the same as students' errors. The term to be used to reflect on students' understandings depends much on the context of concept development and the quantity of knowledge concerned. According to the fundamental views of epistemology expressed by Driver (1989), Piaget (1972) , Pines and West (1986), students constructor generate their knowledge through a set of preconceptions based on previous knowledge and experience and it is termed as constructivist perspective. The net result is that some constructions by students may be erroneous and such misconstructs adversely affect subsequent learning of related concepts.

Electrochemistry is an important branch of chemistry and its knowledge is essential to understand corrosion principles, electrolytic refining and electroplating. There has been hardly any contribution in the area of electrochemistry education till later part of eighties except for some studies like Pfundt and Duit (1991) which documented students' misconceptions in chemical education. Finley, Stewart and Yarroch (1982) have reported that students find the topic of operation of electrochemical cells difficult. Garnett and Treagust (1992) in their article focused on students' understanding of electric currents and the identification and balancing of oxidation reduction equations. Sanger and Greenbowe (1997) reported common student misconceptions in galvanic, electrolytic and concentration cells. Prompted by this study, Sanger (2000) investigated the use of computer animations and instructions based on conceptual change theory to counter students' misconceptions in electrochemistry. Sanger and Greenbowe (1999) analysed ten college chemistry textbooks, identified vague, misleading or incorrect statements in oxidation — reduction and electrochemistry chapters and came out with suggestions concerning electrochemistry instructions intended for teachers and textbook writers. Ogude and Bradley

(1994) investigated on pre-college and college student difficulties regarding qualitative interpretation of the microscopic processes that take place in operating electrochemical cells. Greenbowe (1994) studied the effectiveness of an interactive multimedia software programme and reported that the programme helped students achieve a better conceptual understanding of the processes occurring in electrochemical cells.

The present study investigates the understanding of electrochemical cells held by in-service and pre-service secondary level science teachers and compares their ideas with senior secondary level students' understandings of electrochemical cells. An attempt has been made to remove certain misconceptions held by in-service teachers by inviting them to participate in a teaching-learning sequence for conceptual change. Cho, Kohle and Nordland (1985) defined misconception as conceptual and prepositional knowledge that is inconsistent with accepted scientific consensus. Smith, Blakeslee and Anderson (1993) described conceptual change as a process in which learner realigns, reorganises and replaces the existing misconceptions to accommodate new concepts/ideas. Posner, Strike, Hewson and Gertzog (1982) proposed four conditions to be satisfied before a learner can replace existing misconception. These conditions include:

1. Learner must experience dissatisfaction with the existing conception
2. Learner should understand the new conception
3. The new conception should appear to be plausible
4. The new conception should appear to be better in explaining experiences/ observations.

To bring in conceptual changes in the participating in-service teachers, an opportunity was provided to the teachers to experiment and verify for themselves their own conceptions on the topic. This was followed by discussion on possible misconceptions on electrochemical cells held by different groups as reported in various research reports/articles. The implications for teaching and learning of the topic based on the findings of the research are also discussed.

Method

The study was conducted on a sample consisting of 22 in-service teachers who were Trained Graduate Teachers (TGTs) working in different Jawahar Navodaya Vidyalayas in the country, 90 pre-service teachers (undergoing secondary level teachers' training) and 38 pupils from class XII of Jawahar Navodaya Vidyalaya, Munduli. The in-service teachers were undergoing training in a camp as a part of quality improvement programme. Out of 90 pre-service teachers, 28 were from the final year of 4 year integrated B.Sc. B.Ed. Course, who have opted for applied chemistry subject and the rest were from the final year of 2 year B.Ed. course, who have opted for physical science as one of the method subjects. Except for the pupils of class XII, all others in the sample viz., in-service and pre-service teachers had their schooling and college studies from different institutions of the country. This aspect indirectly has taken care of the possibility of teachers' misconceptions affecting the study.

What concepts are to be taught in the area of electrochemistry at secondary level is decided by the chemistry syllabus framed by the Central Board of Secondary Education (CBSE). The following topics are prescribed for study at secondary level:

1. Sources of Electric current
   (a) Voltaic cell
   (b) Daniel cell
   (c) Dry cell
2. Electric current - charges in motion
3. Chemical Effect of Electric current
   (a) Conductivity of solutions
   (b) Electrolysis
   (c) Electroplating
4. Faraday's laws of Electrolysis

The test items were developed largely based on the syllabus related to electrochemical cells and the principles investigated by the test are generally of basic/fundamental in nature. Each of the nineteen items constituting the test was either multiple-choice or true - false type and investigated teachers'/pupils' understanding of electrochemical cells. For a clear reflection on the understanding of chemical processes at molecular level, some of the multiple-choice type items included visual conceptual questions (especially on electrode reactions).

Results and Discussion

As it is not practically possible to discuss in detail the results of the analysis of all the test items item-wise, only significant findings are described along with comments on the overall performance of in-service teachers, pre-service teachers and pupils.

The Mean scores and standard deviation for each of the groups that participated in the study is presented in Table 1.

There was no significant difference between the Mean score of in-service teachers and that of pre-service teachers and pupils. The research studies of Butts and Smith (1987), Finley, Stewart and Yarroch (1982) suggest that the students find the topic on operation of cells

Table 1: Group Means and Standard Deviation for all items in the Questionnaire

Group	*N*	*Mean*	*SD*	*t-values*	
				1 and 2	*1 and 3*
In-service Teachers (1)	22	8.81	2.57	0.55	0.97
Pre-service Teachers (2)	90	8.43	2.97		
Pupils (3)	38	9.47	2.36		

difficult. The inability of students to master certain basic concepts in the topic, perhaps, handicaps them even after taking up teaching assignments at secondary level. Another interesting finding of the study is that among the pre-service teachers, the four-year integrated B.Sc.B.Ed. students appeared to possess a better understanding of the basic principles of electrochemical cells. This is evident from Table 2 in which the Mean score of Four year integrated B.Sc.B.Ed. students is significantly different from that of two-year B.Ed. students. The pupils' Mean score did not differ significantly from the Mean score of pre-service teachers undergoing B.Sc.B.Ed. course. However, the pupils' Mean score differed significantly from that of pre-service teachers undergoing two-year B.Ed. programme.

The reasons for this significant difference could be many. One of the possible reasons could be that the four-year integrated students join the course after +2 and study the content integrated with methodology all through the four years where as two-year B.Ed. students join the course after graduation/post-graduation and concentrate more on pedagogical aspects and less on content competencies.

The pre-test was administered to in-service teachers, who were undergoing training in a camp. According to Champagne, Gunstone and Klopfer (1985), Roth, Anderson and Smith (1987) and Smith, Blakeslee and Anderson (1993) any conceptual change instructions involve discussions on possible students' misconceptions. As a follow-up, the participants were exposed to experiments on electrochemical cells and it was followed by a thorough discussion on the general misconceptions of pupils in the area as reported by Sanger and Greenbowe (1999) and (2000), Garnett and Treagust (1992). This session enabled the teachers to come across a variety of pupils' misconceptions in the area and compare their own understandings with those of pupils. This exercise brought in a visible conceptual change in the participating teachers and this was evident from the post-test scores as summarised in Table 3.

Table 2: Comparison of Mean Scores of Pre-service Teacher Groups and Pupils

Group	*N*	*Mean*	*SD*	*t-values*		
				1–2	*1–3*	*2–3*
4 - yr B.Sc.B.Ed (1)	28	9.82	2.90	3.08*	0.52	3.19*
2 - yr B.Ed (2)	62	7.8	2.81			
Pupils (3)	38	9.47	2.36			

* Significant at 0.01 level

Table 3: Comparison of Pre-test and Post-test Scores of In-service Teachers

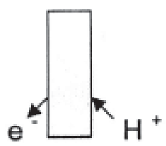
Group	*N*	*Before activity*		*After activity*		*t-value*
		Mean	*SD*	*Mean*	*SD*	
In-service Teachers	22	8.81	2.57	11.86	3.34	3.37*

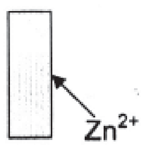
* significant at 0.01 level

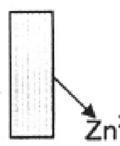
Since chemical processes taking place on molecular level can't be practically seen during experimentation, one of the effective ways to understand such processes is through either computer animation or static visuals. In the absence of animations, the authors used static visual conceptual questions to investigate into the in-service teachers', pre-service teachers' and pupils' understanding of reactions taking place at the electrodes in simple voltaic and Daniel cells. Some of the questions, which led to the identification of misconceptions in teachers, are as follows:

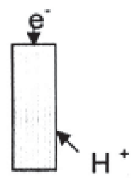
On simple Voltaic Cell (a diagrammatic representation given)

Q. 1. Which of the following describes best the reaction-taking place in solution at the zinc electrode?

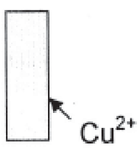
(i) 

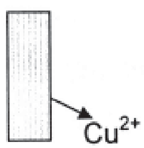
(ii) 

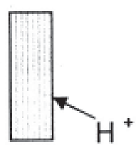
(iii) 

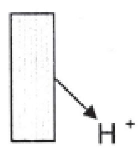
(iv) 

Q.2. Which of the following best describes the reaction-taking place in solution at the copper electrode?

(i) 

(ii) 

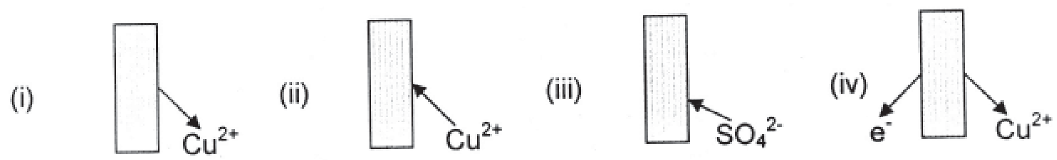
(iii) 

(iv) 

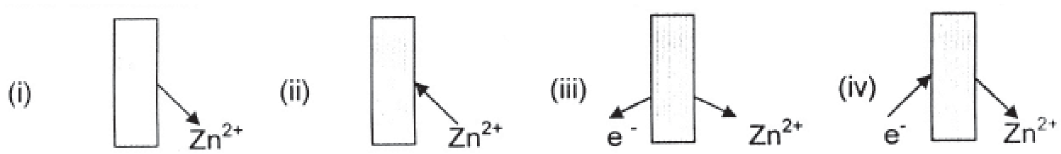
True or False Type Questions	**True**	**False**	**I don't Know**
Q.3. Electrons flow through the wire towards zinc electrode	( )	( )	( )
Q.4. The electrode sign convention in electrochemical cells and Electrolytic cell is same	( )	( )	( )
Q.5. Graphite can be used instead of copper electrode	( )	( )	( )

On Daniel Cell (a diagrammatic representation given)

Q.6. Which of the following best describes the reaction-taking place in solution at the copper electrode?



Q.7. Which of the following best describes the reaction-taking place in solution at the zinc electrode?



True or False Type Questions	**True**	**False**	**I don't Know**
Q.8. The electrons flow from copper electrode to zinc electrode in the external circuit.	( )	( )	( )
Q.9. The function of salt bridge is to allow the migration of electrons from one solution to another.	( )	( )	( )
Q.10. If zinc (s) and zinc sulphate (aq) are replaced with silver (s) and silver nitrate (aq), copper is oxidized.	( )	( )	( )

The results of the analysis of responses to the above static visual conceptual questions and True or False type questions are summarised in Table 4.

Table 4. Spread of views on Electrochemical Cells held by In-service and Pre-service Teachers and Pupils

Question No.	*Group*	*Response (%)*			
Visual Questions		(i)	(ii)	(iii)	(iv)
1.	In-service	4.5	4.5	36	40.5
	Pre-service	18.8	12.2	46.6	14.4
	Pupils	29	29	31.5	10.5
2.	In-service	31.5	54	—-	9
	Pre-service	22.2	32.2	20	6.6
	Pupils	34	26	23.6	15.8
6.	In-service	27	36	4.5	22.5
	Pre-service	25.5	25.5	8.8	28.8
	Pupils	21	36.8	29	13.2
7.	In-service	10	4.5	36	18
	Pre-service	15.5	26.6	24.4	18.8
	Pupils	26.3	31.5	15.8	26.3

Question No.	*Group*	*Response (%)*		
		True	*False*	*I don't Know*
True/False Type Questions				
3.	In-service	41	50	9
	Pre-service	43	55	2
	Pupils	40	60	—
4.	In-service	23	41	38
	Pre-service	45	42	13
	Pupils	21	74	5
5.	In-service	64	27	9
	Pre-service	27	58	15
	Pupils	26	63	11
8.	In-service	45	36	19
	Pre-service	60	36	4
	Pupils	53	47	—-
9.	In-service	72	5	23
	Pre-service	49	40	11
	Pupils	68	32	—-
10.	In-service	54	23	23
	Pre-service	39	38	27
	Pupils	42	47	11

Visual Conceptual Questions

Q.1. About 40% of in-service teachers and 18% of the total sample believed that hydrogen ions in solution accept electrons at zinc electrode in voltaic cell. On further probing, different reasons were cited for this view and they are summarised below:

(a) Hydrogen gas is liberated at zinc electrode because we see gas bubbles surrounding this electrode

(b) Hydrogen ions in solution accept electrons at zinc electrode liberating hydrogen gas

(c) Electrons are available around zinc electrode in solution

(d) Zinc reacts with acid giving zinc ions. The electrons lost from zinc are available at the zinc electrode for hydrogen ions.

Q.2. About 54% of in-service teachers and 40% of total population believed that copper ions are produced from copper electrode in the voltaic cell. On further probing, the following reasons were cited for the option:

(a) Copper is cathode and so electrons lost by copper move to anode in the wire

(b) Electrons lost by copper move to zinc electrode through solution and then to copper through wire

(c) Electrons are available in solution around copper electrode.

Q.6. On Daniel cell, about 25% of the sample opted for (i) whereas 22% opted for (iv). The reasons quoted for the choice include:

(a) Copper ions are formed from copper at this electrode

(b) The electrons lost by copper move through wire to zinc electrode — leading to flow of current. Current flow detected by deflection in ammeter

(c) Copper ions are formed by the loss of electrons and these electrons move into solution.

Q.7. About 36% of in-service teachers and 25% of total population believed that the electrons lost from zinc would move into solution.

True or False Type Questions

Q.3. About 42% of the population believed that the electrons flow through the wire towards zinc electrode in voltaic cell.

The reasons cited for the response include the following:

(a) Zinc is anode (+) as it loses electrons and Copper is cathode (-) as it gains electrons. Electrons flow from cathode to anode

(b) Zinc loses electrons and these electrons reach the copper electrode through solution and then pass from copper to zinc through the wire

Q.4. About 30% of the sample believed that the electrode sign convention in electrolytic cells and electrochemical cells is same. The reason quoted for the belief was —

- Anode is always positive and cathode is always negative.

Q.5. A majority of the sample – 63% of pupils and 58% of pre-service teachers believed that graphite couldn't be used instead of copper electrode for the reasons:

(a) Graphite may not work, as it is an inert electrode

(b) Graphite being non-metal, it will not conduct electricity.

Q8. About 60% of pre-service teachers 53% of total sample believed that in Daniel cell, electrons flow from copper electrode to zinc electrode in the external wire. The reasons for holding this view include:

(a) Zinc loses electrons. These move towards copper in solution and then flow from copper to zinc through wire

(b) Copper is cathode here. That's why electrons flow from copper to zinc.

Q.9. A major group corresponding to 72% of in-service teachers, 68% of pupils and 49% of pre-service teachers were of the opinion that salt bridge allows migration of electrons from one solution to another. The explanations given for holding the view include

(a) Without salt bridge how electrons move to complete the circuit?

(b) There will be flow of current only if electrons could flow through salt bridge

(c) Salt bridge establishes a connection between two half cells by allowing flow of electrons.

Q.10. About 38% of pre-service teachers and 47% of pupils had a notion that in Daniel cell, when copper and silver are used as electrodes, copper is not oxidized because –

(a) Among silver and copper, silver is more reactive and so it can be easily oxidized

(b) Copper is very less reactive than many metals like zinc, iron, etc.

(c) Standard oxidation potentials decide this. Oxidizing strength of copper appears to be higher.

The analysis of responses given by the pre-service teachers and pupils and the ensuing discussion with them led the authors to believe that the under-standings held by pre-service teachers and pupils were more or less similar to the understandings of in-service teachers.

The in-service teachers, after the administration of Questionnaire on Electrochemical cells, were exposed to conceptual change instructions as a part of inservice training. The instructions include experimentation on Voltaic and Daniel cells, representation of chemical processes on molecular level through visual pictures and discussion on possible misconceptions of students in electrochemical cells. The post-test was conducted after a gap of one week on the last day of the training programme. Although there was a marked improvement in the overall performance, the participants did not fare much better as expected particularly in the visual conceptual questions category. On investigation, it was found that teachers were not comfortable in answering static visual questions because of unfamiliarity and confusing nature of the pictures depicted. This could be due to the fact that the visual conceptual questions are not generally used in textbooks and classrooms for teaching-learning processes. Nurrenbern and Pickering (1987), Pickering (1990) and Sawrey (1990) have also expressed similar views in their research reports. Willows (1978) and Dwyer (1979) reported about the distractive nature of static visual pictures and Dwyer concluded that such pictures need more processing time and better abilities to understand and work with.

Conclusions

The present study enabled the investigators to identify some misconceptions that are common to the whole sample, which consisted of in-service teachers, pre-service teachers and pupils. The most commonly encountered misconceptions in the sample are summarised in Table 5.

The results also suggest that the conceptual change instruction strategy adopted in the study is effective in removing misconceptions of in-service teachers. The implications of the present study for teaching and learning of electrochemical cells at secondary level are as follows:

- Electrochemistry being a difficult topic for students to understand, simple chalk and talk method will not facilitate learning of basic concepts
- Experimentation on galvanic cells, explanation of various chemical processes at electrodes through static visual pictures and a thorough discussion on possible misconceptions in learners would help students to learn the basic concepts better.

Table 5: **Some Misconceptions of In-service and Pre-service Teachers and Pupils in Electrochemical Cells**

1. Electrons flow in solution
2. Electrons flow from anode to cathode in solution
3. The flow of electrons in solution and in external circuit constitute an electric current
4. Electrons flow through the Salt bridge
5. Salt bridge facilitates migration of electrons from one half cell to another
6. Anode is always positively charged and cathode is always negatively charged.
7. Silver is more easily oxidized than copper
8. Cathode is negatively charged and electrons move from copper (cathode) to zinc (anode) in Daniel cell
9. Inert electrodes can't be used as no reaction takes place at these electrodes 10.
10. Anode is positively charged due to loss of electrons and cathode is negatively charged as it gains electrons
11. Hydrogen gas is liberated at zinc electrode in voltaic cell
12. Copper ions are formed at copper electrode in voltaic cell.

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