CONSTRUCTIVIST MODEL TO ENCOUNTER LANGUAGE MISCONCEPTIONS, PRIOR KNOWLEDGE OVERGENERALIZATIONS AND VISUALIZATION ERRORS IN ELECTROCHEMISTRY

MUZAMMILA AKRAM

UNIVERSITI TEKNOLOGI MALAYSIA

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MUZAMMILA AKRAM

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To My beloved mother, siblings & husband for their unwavering love, sacrifice, patience, encouragement and best wishes.

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Muzammila Akram,
Faculty of Education,
University Teknologi Malaysia

ABSTRACT

The problem of misconceptions has become more critical when students have to acquire science concepts in a second language. Moreover, students' misconceptions might vary by region, culture, gender or age and to students with the misconceptions, it is essential to identify the reasons behind it. The present study identified the misconceptions in electrochemistry, and reasons for these misconceptions among second language science students of a secondary class in Pakistan. Many researchers have indicated that electrochemistry is considered a difficult topic for students to learn. The research developed a constructivist model to encounter language misconceptions, prior knowledge overgeneralizations and visualization errors after identifying electrochemistry misconceptions. It was conducted in two phases. During phase-I, grounded theory was used to identify electrochemistry misconceptions and its reasons, and a model in light of constructivist theories was developed. Data were collected via Test designed to identify Misconceptions in Electrochemistry, diagnostic test interview, think aloud protocol, concept mapping, and eminent chemistry teachers. In phase-II, the process of teaching using the new model was observed after training was given to two volunteer teachers. Students who had studied based on the new model were purposively selected for an interview. The findings of phase-I data were used to develop a Constructivist Model to Encounter the Misconceptions in electrochemistry. The findings of phase-II showed that model was effective to encounter language misconceptions, prior knowledge overgeneralizations and visualization errors in electrochemistry. The present study concluded that the diagnosed misconceptions helped to produce a disequilibrium state among second language science students leading to assimilation and accommodation. In this study, second language science students were found to use complex content related vocabulary and technical terms in the presence of a more knowledgeable person (teacher and peer in the zone of proximal development).

ABSTRAK

Masalah kesalahfahaman telah menjadi semakin kritikal apabila pelajar perlu memperoleh konsep sains dalam bahasa kedua. Selain itu, kesalahfahaman pelajar ini berbeza-beza mengikut wilayah, budaya, jantina atau umur. Untuk menghadapi kesalahfahaman pelajar ini, adalah penting untuk mengenal pasti sebab-sebab berlakunya situasi ini. Oleh itu, kajian ini adalah untuk mengenal pasti kesalahfahaman dalam bidang elektrokimia serta sebab-sebab kesalahfahaman ini berlaku dalam kalangan pelajar sains yang menggunakan bahasa kedua di peringkat kelas menengah di Pakistan. Penyelidik telah membuktikan bahawa elektrokimia dianggap sebagai topik yang sukar bagi pelajar untuk mempelajarinya. Kajian ini membangunkan model konstruktivis untuk menghadapi kesalahfahaman bahasa, pengetahuan umum yang keterlaluan dan kesilapan visualisasi selepas mengenal pasti kesalahfahaman elektrokimia. Ia telah dijalankan dalam dua fasa. Semasa fasa-I, teori '*grounded*' telah digunakan untuk mengenal pasti kesalahfahaman elektrokimia dan sebab-sebabnya serta membangunkan model berdasarkan teori konstruktivisme yang telah dibangunkan. Data telah dikumpul melalui ujian yang direka untuk mengenal pasti kesalahfahaman dalam Elektrokimia, ujian temuduga diagnostik, protokol semasa berfikir, pemetaan konsep dan guru-guru kimia yang terkemuka. Dalam fasa-II, proses pengajaran menggunakan model baharu diperhatikan selepas latihan diberi kepada dua orang guru secara sukarela. Pelajar yang telah dikaji berdasarkan kepada model baharu telah dipilih untuk ditemuduga. Dapatan data daripada fasa-I telah digunakan untuk membangunkan Model Konstruktivis untuk mengenal pasti kesalahfahaman dalam elektrokimia. Hasil fasa II menunjukkan bahawa model tersebut berkesan untuk menghadapi kesalahfahaman bahasa, pengetahuan umum yang keterlaluan dan kesilapan visualisasi dalam elektrokimia. Kajian ini merumuskan bahawa kesalahfahaman diagnosis dapat membantu menghasilkan keadaan yang tidak seimbang dalam kalangan pelajar sains yang menggunakan bahasa kedua yang membawa kepada asimilasi dan kemudahan. Dalam kajian ini, pelajar sains menggunakan bahasa kedua di dapati menggunakan perbendaharaan kata yang berkaitan kandungan dan istilah teknikal yang kompleks di hadapan individu yang lebih berilmu (guru dan rakan sebaya dalam zon perkembangan proksimal).

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LIST OF ABBREVIATIONS

TME	-	In this study, TME stands for Test designed to identify the Misconceptions in Electrochemistry
CEM2	-	Constructivist Model to Encounter Misconceptions
IX CLASS	-	In this study, it means ninth Class of Government Secondary Schools
DCT	-	Dual Coding Theory of Visualization
PKO	-	Prior Knowledge Overgeneralization
VE	-	Visualization Error
LM	-	Language Misconceptions
DTCEM	-	Double Triangular Chemistry Education Metaphor
ZPD	-	Zone of Proximal Development

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The relevance of science as a solid rock for the technological progression of any nation cannot be underestimated. Every citizen needs a basic knowledge of science and technology to function productively and intelligently in this era. Chemistry is the field of science filled with interesting phenomena tempting for understanding and explaining every occurrence in the natural and manufactured world. Its study has incredible importance to humanity for its ability to explain natural phenomena and everyday happenings. It plays central role in current technological development of the world. Its knowledge is important in the manufacturing of fertilizer, food storage and processing, management of natural resources, provision of health facilities as well as favorable living environment. The science of chemistry creates a natural link between home and school. It provides the means through which children understand the world around them and explore the wider implications of science (Bomide, 1985).

Chemistry is the science of matter concerned with the composition of substances, structure and properties between them. Chemistry education is a comprehensive term that refers to the teaching and learning of chemistry in all schools, colleges and universities. Topics in chemistry education might include understanding how students learn chemistry and how best to teach chemistry. It also involves how to improve concept formation by changing teaching methods and proper training of chemistry teachers in classroom lecture, demonstrations and laboratory activities. Chemistry education is facing many challenges in most of the countries at secondary level. These challenges cannot be overcome only by considering the teaching of chemistry. Nevertheless, it requires a comprehensive effort to assess conceptual knowledge of chemistry that school students learn in secondary schools (Ogude, 1994; Ozkaya, 2002). Concept formation and learning attitude towards chemistry at secondary school depends upon various factors. Many research studies have indicated that concept formation in chemistry is a big challenge at all levels of schooling for many students and even for teachers (Dawson, 1978; Taber, 2002).

Concepts are thoughts or notions formed in the mind as the product of careful mental activity. Concepts formed when the ideas or thoughts are developed based on common properties of objects or events by the process of abstraction. These are powerful building blocks for learning. These concepts play significant role in the teaching of chemistry and for further learning (Taber, 2002). When concepts become difficult for students or forms misconceptions, they tend to shy away from questions set on these concepts during any examination leading to poor performance. Difficulties ascended when students' ideas or thoughts became different from the definitions accepted by experts. These incorrect ideas referred as misconceptions or alternative conceptions (Griffiths, 1994; Nakhleh, 1992). Several studies in the chemistry education literature dealt with the misconceptions of basic concepts of chemistry at schools. Duit (2007) conducted a study on students' misconceptions in science and found that instruction often failed to engage those ideas that students carry to the classroom. Student's misconceptions in chemistry created a major problem of concern to science educators, teachers and students (Ozmen, 2004). Electrochemistry regarded as one of the most difficult chemistry concepts in which both pre-service teachers and students have learning difficulties (Nakhleh, 1992; Ogude, 1994; Ozkaya, 2002).

The study of electrochemistry required qualitatively and quantitatively understanding. It involved in the transfer of electrons between different chemical species. Students should clearly hold the basic concept that this transfer is just a specific type of chemical reaction that followed all the principles of other chemical reactions. Electrochemistry considered as a complex subject that has substantial importance in many applications from battery development to neuroscience. A number of researchers investigated the misconceptions of students and teachers in electrochemistry topics (Doymus, Karacop and Simsek, 2010; Garnett and Treagust, 1992a, 1992b; Ogude and Bradley, 1994; Ozkaya, 2002; Sanger and Greenbowe, 1997a, 1997b).

For the current study, topic of electrochemistry was selected for a number of reasons as cited by Akram (2014). For example, electrochemistry considered as a difficult topic for students to learn and for teachers to teach. A survey conducted to rate the most difficult chemistry topics at schools and the top three were chemical equilibrium, the mole and oxidation-reduction reactions (Finley, Stewart and Yarroch, 1982). Principles of electrochemistry had general applications used in routine e.g. electroplating established based on the principle of electrolytic cell. Students should acquaint such knowledge (Ahtee, Asunta and Palm, 2002). Moreover, the topic of electrolysis was common in physics and chemistry. Sometimes, it promoted confusion and students did not freely assimilate their knowledge across physics and chemistry (Taber, 1998).

Garnett and Treagust (1992b) investigated high school students understanding of electrochemistry in terms of electrochemical cells and identified students' misconceptions. In 1997, Sanger and Greenbowe replicated the study of Garnett and Treagust (1992b) with college chemistry students and found similar findings with them as students had misconceptions in galvanic, electrolytic and concentration cells. Obomanu (2012) also identified the conceptual difficulties and misconceptions of Nigerian secondary school students in electrolysis through concept inventory. Moreover, Sanger and Greenbowe (1997a) emphasized that identifying misconceptions was important to help learners understand this topic meaningfully. The misconceptions of students may change with the change in variables like gender, age, culture, religion and geographical region (Losh, 2003).

Literature showed that Pakistani secondary school students found chemistry as a difficult subject and possessed conceptual difficulties in its many topics (Akram, 2014; Ali, 2013). Chemistry is the compulsory subject for all secondary school students of science group in Pakistan. The pass percentage in the subject of chemistry is very low, about 50% as mentioned in Figure 1.1.

Year	Total no. of Students appeared in SSC (IX) Examination	No. of Passed Students	% age of Passed Students
2009	43367	20841	48.05
2010	46433	22972	49.47
2011	49870	21643	43.39
2012	54294	29782	54.85
2013	55300	31054	56.15

(Source: Bahawalpur Board of Intermediate & Secondary Education)

Figure 1.1 Students Result in SSC (Secondary School Certificate) Examinations in the subject of Chemistry for Class IX (2009-2013), Adapted from Akram (2014).

Akram (2014) described the factors that have contributed to this problem. These factors included poor methods of instruction, instruction in second language, laboratory inadequacy, poor science background and passive role of students etc. Usually students had problems in understanding the complex and abstract natured phenomena of chemistry like oxidation and reduction reactions and electrolysis (Ahtee, Asunta and Palm, 2002). Misconceptions in electrochemistry were common and students had difficulty to understand (Obomanu, 2012). Researchers had made many attempts in many advanced countries to assist students learning by identifying the misconceptions experienced by students and possible solutions to overcome this problem (Sanger and Greenbowe, 1997a and 1997b; Niaz and Chacon, 2003; Ozmen, 2004; Ozkaya et al., 2006). Some studies also suggested ways of remedying conceptual difficulties about electrochemistry in the literature. These studies used one conceptual change method as a basic technique that is computer animations (Yang andre and Greenbowe, 2003) or computer-assisted learning (Talib, Matthews and Secombe, 2005) or conceptual change instruction (Huddle, White and Rogers, 2000). However, in Pakistan and in many other developing countries, very little research work has been done in identifying the misconceptions of their own students particularly in the abstract natured chemistry concepts. Most Pakistani Schools are not well equipped to use computer-assisted learning as a single solution for encountering the misconceptions (Akram, 2014).

Moreover, electrochemistry misconceptions were reported previously among the learners who were learning chemistry in their first language English (Garnett and Treagust, 1992; Sanger and Greenbowe, 1997a and 1997b; Ahtee, Asunta and Palm, 2002). While, in Pakistan, academic courses such as mathematics and sciences taught in a foreign language i.e. English. English is the second language or sometimes third language of all the students of Pakistan. When they tried to understand the concepts, they translated it into Urdu that might develop misconceptions (Halai, 2007). Both Garnett and Treagust (1992a) and Ogude and Bradley (1998) found that inappropriate language in explaining the electrochemical concept might cause misconceptions. Various research studies indicated that students who study main courses in a foreign language had difficulty connecting new and old information meaningfully. Pollnick and Rutherford, (1993) exposed that learning in chemistry through the medium of second language developed problems for students. Johnstone and Selepeng (2001) conducted an experimental research and concluded that students who were learning science in a second language lost at least 20 percent of their capacity of understanding and reasoning.

Thus, the problem became more critical when second language was used in communicating the scientific concepts. Cassels and Johnstone (1980) exposed that the non-technical words associated with science were a cause of misunderstanding for students. Words, which were understandable in normal English usage, changed their meaning (sometimes quite slightly) when used in science situation. Akram (2014) reported that language misunderstanding found to be an important factor that caused conceptual difficulties among secondary school students of Pakistan. Hence, there was a great need to help secondary school students who were learning chemistry in their second or sometimes third language to overcome their misconceptions of electrochemistry. The present study intended not only to diagnose misconceptions but also tried to identify the reasons behind these misconceptions. Moreover, this investigation also shed light on how students develop misconceptions. This study anticipated making logical connection between knowledge in a second language instructed to students and the students developed misconception as a result.

From Vygotsky (1962) perspective, dialogue with the teacher and peers played crucial role in concept formation. The use of constructivist teaching and learning models would help teachers to enhance students learning by removing the electrochemistry misconceptions. There are different validated and reliable teaching models based on constructivist learning approaches. The present study intended to review these models for guidance and tend to modify these models regarding with use of second language in concept formation. Hence, present study aimed to develop a constructivist model for second language science students to encounter electrochemistry misconceptions after diagnosing the misconceptions and its reasons.

1.2 Background of the Study

The background of the study comprised of the concept of misconceptions, reasons behind misconceptions, use of second language and misconceptions and need of new constructivist model with context to Pakistan. All these headings explained in the following.

1.2.1 Misconceptions

Skelly and Hall (1993) defined a misconception as a mental representation of a concept that did not match to a proper scientific theory. They divided misconception into two categories: experiential and instructional. Experiential misconception referred to as alternative, intuitive or native conceptions. In experiential misconception, a concept tried to be understood to some extent, through everyday experience and interaction with the phenomena involved. Meanwhile instructional misconception defined as misconceptions related to these more abstract phenomena resulted from some instructional experience. Students' misconceptions in science found a major problem of concern to science educators, teachers and students. The researchers and teachers were interested to know the nature of misconceptions, the source of these misconceptions and the effects of instruction on elimination of misconceptions (Ozmen, 2004). During concept formation, the students tried to connect new knowledge into their existing schema. If they held misconceptions, these misconceptions obstructed their subsequent learning. The prior misconception developed further misconceptions (Nakhleh, 1992).

A number of researchers explored students as well as teachers' misconceptions in electrochemistry (Doymus, Karacop & Simsek, 2010; Garnett & Treagust, 1992a, 1992b; Nakhleh, 1992; Ogude & Bradley, 1994; Ozkaya, 2003; Sanger & Greenbowe, 1997a, 1997b). Sometimes, the topic of electrolysis, which was common in physics and chemistry, caused more confusion. Students did not freely assimilate their knowledge across physics and chemistry (Taber, 1998). The workshop, Integrated Physics and Chemistry Modeling Workshop, was conducted at Arizona State University (ASU) in June 2001. This workshop was carried out to identify the key misconceptions in chemistry and physics. The key misconceptions in electrochemistry were selected from catalog recommended by eminent participants of workshop. The electrochemistry key misconceptions were used in TME (Test designed to measure misconceptions in electrochemistry) for identifying the presence of misconceptions among second language science students of Pakistan for present study.

Science student often held misconceptions and it became difficult for the teachers to reorganize their thinking. Misconceptions became resistant to instruction because learning involved radically reorganizing students' knowledge. It was not easy to reorganize students' existing ideas towards scientific ideas. Barke (2009) suggested that every science teacher should know his own students' misconception. Students' misconceptions were deeply rooted and extremely complex by a number of sources. Likewise, the students' misconceptions often vary by geographical region, culture, religious background, gender and age (Losh, 2003). In order to diffuse student's misconceptions, it is essential to identify the reasons behind these misconceptions.

1.2.2 Reasons behind Misconceptions (Language Misunderstandings, Prior Knowledge Overgeneralizations and Visualization Error)

During last twenty years, with increase in identification of misconceptions researches, the researchers intended to know the nature of misconceptions. They also showed interest in recognizing the reasons of these misconceptions and the effects of instruction on elimination of misconceptions (Ozmen, 2004; Acar & Tartan, 2006; Sanger & Greenbowe, 1997; Ozkaya, Uce & Sahin, 2003; Schmidt, 1997; Akram, 2014). Reasons for the misconceptions were varied, including textbook authors and teachers who were guilty of making unintentional simplifications or using ambiguous and misleading terminology (Acar & Tartan, 2006; Sanger & Greenbowe, 1999).

Ozkaya, Uce & Sahin (2003) gave the reasons of considering the electrochemistry as a difficult subject. They argued that the particles and their movement could not be seen with the eye and thus teaching of the abstract natured electrochemistry topic was challenging. They also recommended further research to improve instruction to encounter this problem. Students faced difficulties in understanding the abstract chemical processes especially at microscopic and symbolic levels. Sometimes, they overgeneralized prior knowledge in constructing the new concepts due to abstract natured chemistry topics (Garnett & Treagust, 1992; Lee & Arshad, 2009; Lin, 2002; Sanger & Greenbowe 1997a; Sanger & Greenbowe 1997b).

Some researchers identified the main reasons of misconceptions as inconsistent terminology during instruction and in textbooks that leads to generalizations or overgeneralizations by students (Abimbola, 1988; Ogude & Bradley, 1994). Ozkaya (2002) investigated conceptual understanding and difficulties in acquiring scientific concepts of electrochemistry. He recognized this problem due to inadequate explanations of the electrochemistry concepts in the textbook. Students who learn electrochemistry from most high school textbooks had conceptual difficulties on this topic (Birss and Truax, 1990). Textbooks and its diagrams provided visual representation to the students. Improper labelling of textbooks diagrams developed visualization misunderstandings. Vavra (2011) described the term visualization used to name a representation, refer to the process of creating a graphical representation or as a synonym for visual imagery. Students visualized the (-) sign as electrons in electrolyte. Improper visual presentation in the textbooks originated some electrochemistry misconceptions (Garnett & Treagust, 1992a, 1992b; Ozkaya, 2003).

Akram, (2014) reported the factors that developed conceptual difficulties in electrochemistry among secondary school students of Pakistan. These factors included misunderstanding of language, poor background of knowledge, absence of teaching aids, rote learning, saturated classes and passive role of students that caused difficulty in comprehension. The study reported that twelve students out of thirty told that their mathematics teacher was teaching them chemistry. The results obtained through quantitative data of TCDE (Test designed to measure Conceptual Difficulties in Electrochemistry) also proved that these students calculated the oxidation number very well but failed to explain its mechanism. Previous researches also pointed out that some teachers failed to provide accurate information to their students and they presented the concepts poorly. Teachers could also be a source of misconceptions because most students regarded their teachers as experts and considered their words correct (Ogude, 1994; Ozkaya, 2002).

Terms with multiple meanings caused general confusion to students in abstract natured chemistry concepts. For example, "Electrolysis definition interpreted by students as breaking apart chemically of substances due to electricity", this misinterpretation could develop alternative concepts about electrolysis (Schmidt, 1997). Many school-made misconceptions developed because there were problems with the specific terminology and the scientific language. For example, students could not differentiate properly between substances, particles and chemical symbols (Barke, 2009).

1.2.3 Use of Second Language and Misconceptions

Research in science education indicated misconception contribution on students learning outcomes. Misconceptions should not be considered a simple problem and could not be taken for granted. The problem of misconception became worse when science students had to acquire scientific concepts in second language. Kocakulah, (2005) conducted a study that described the effect of teaching mathematics and science in a second language. He found that teaching sciences and mathematics through a medium of second language posed conceptual and linguistic problems among students.

Studies by Cassels and Johnstone (1983, 1985), Pollnick and Rutherford, (1993) revealed that the medium of English developed problems for students whose mother tongue was not English in learning academic courses such as sciences and mathematics. One of the major problems was rote learning of the scientific concepts. Students who studied science in a foreign language had difficulty connecting new and prior information meaningfully. It was found that they could not construct knowledge based on prior knowledge and possessed language misconceptions. Use of second language established misunderstanding of meanings of words used in different contexts that ultimately caused misconceptions (Pollnick and Rutherford, 1993).

Comins (1993) discussed the different causes of misconceptions and exposed that usually students focused on the superficial sources of knowledge. Language misunderstanding considered as one of the basic factor that developed the misconceptions. Words in everyday usage had specific uses in sciences that students could not understand due to superficial thinking. Mowshowitz, (2013) discussed the problems of terminology that caused language misconceptions in science education. For example, confusion of the words that had different ordinary meanings and the technical meanings used in sciences. Some scientific terms had technical meanings that were very different from their common sense meanings. For example, the word spontaneous in chemistry did not mean, very quick. It meant without net input of energy. Using words that had technical meanings and not realizing it. For example, if the house burnt down, the house would destroy (in the English sense). However, the atoms were in the house had not been altered. Sometimes, students got confused in using similar but not identical terms. For example, a reasonable, nonscientific interpretation of a supernova was a bigger nova.

Bird and Welford (1995) also showed that there was significant difference between British school learners and second language learners. The second language students' performances in science examinations were poor comparatively. Poor knowledge of grammar rules and complex content related vocabulary developed problems for second language learners to read and understand the text. Whereas, first language learners had inherent knowledge of learning their language at an early stage, did not show these problems (Johnstone and Selepeng, 2001).

The above-mentioned studies were consistent with Vygotsky's perception on learning and development. Vygotsky (1978) proposed two fundamental roles of language in the learning process: (1) Language provided accommodations for learning. It meant that learning occurred in a social context. (2) Language considered as a tool that helped the learner to construct a new way of thinking. Vygotsky strongly claimed that concepts could not be constructed meaningfully without language. For language acquisition, students should receive meaningful and understandable communications. Moreover, students should learn in an environment with no anxiety (Collier, 1995; Vygotsky, 1978).

Pakistan considered as a linguistically diverse country and approximately 57 languages were reported to speak throughout the four major provinces of country (Khan, 2002). Whereas, Urdu is the national language of country and it is the primary language. Less than 10 percent of the populations speak Urdu others preferred to speak their native mother languages (Laporte, 1998). English considered as the preferred language of education. In English medium science and mathematics classrooms, the learning process became more complex. It was due to the socio-cultural tools that students used often included their first language, which was different from their language of instruction. For example, students moved from the language of instruction to their own language during learning the science and mathematics. Students' concentration divided into two levels. They had to understand the language involved at first level and then they had to understand the scientific concepts involved at second level. Science students needed to understand the language of instruction before they made sense of the scientific concepts encoded in that language. The students used Urdu in thinking during learning process. This attempt of interpreting the language of instruction (second language) into students' first language developed misconceptions in multilingual classrooms of Pakistan (Halai, 2007).

Moreover, Akram (2014) reported factors that developed conceptual difficulties in electrochemistry among second language science students of secondary class at Pakistan. These factors included misunderstanding of language, poor background of knowledge, absence of teaching aids, rote learning, saturated classes and passive role of students. Language misunderstanding was found as major factor of developing conceptual difficulties in electrochemistry. For example, second language science students misunderstood the terms electrons and negative ions because of its Urdu translation as "manfi zarrat". Another research study was conducted by Aziz (2014) to find out the learning difficulties and strategies of students who were learning in a second language at higher secondary schools of Pakistan. She found that higher secondary schools students were interrupted by mother language during learning process. Teachers could play a significant role to overcome the students' misconceptions. The first step was to diagnose students' misconceptions. The next was to find out the best solution about that. Teachers should focus on students' thinking process and focus on how students develop misconceptions to eliminate it (Abraham, Williamson and Westbrook, 1994).

Teachers should use a multidisciplinary approach that integrated technology with effective teaching and learning practice. Ordinary instructional methods like lectures, labs or simply reading texts, were not found successful for challenging secondary school students misconceptions in electrochemistry (Akram, 2014). Various teaching models agreed that students became active in construction of knowledge by asking questions, experimenting and communicating with their classmates. Before proceeding further, it would be important to have a general view of the various constructivist models that help teachers in developing concept formation. A comprehensive analysis of existing constructivist models and how these models helped in developing the new constructivist model with context to Pakistan was described in the following.

1.2.4 Need of New Constructivist Model with Context to Pakistan

During the 1980's and 90's a constructivist model of learning appeared to be the dominant theme in science education. Research into students' misconceptions was very extensive. However, Millar (1989) recognized that a model of learning was not the same as a model for teaching and that how constructivist models of learning might be translated into specific teaching approaches was far from clear. Richardson (2003) argued the important unresolved issue related to the difficulty in translating a theory of learning into a theory of teaching. This issue demanded more researches focused on students learning using constructivist instruction.

Constructivist approach believed that learning took place only when the learners related the new information to their already existing knowledge. Knowledge did not transfer to the learner's mind from a textbook or by the teacher. Instead, students construct their own knowledge by connecting between their prior concepts and new concepts through experiences (Merriam, Caffarella and Baumgartner, 2007). Constructivist perspectives on learning had given rise to a number of models for constructivist teaching e.g. conceptual change model, Driver teaching model, 5E instructional model, Needham's five-phase constructivist model, Osborne generative model. Theses constructivist models facilitated the present study in developing a modified constructivist instructional model for confrontation of misconceptions with context to the use of second language at Pakistan.

Current constructivist instructional models embedded in a Piagetian-focus (1970) that seeks to resolve student misconceptions properly. Models that were more progressive also included the Vygotskian notion of scaffolded learning through the principle of zone of proximal development (1978). Collectively, the work of Piaget and Vygotsky provided an appropriate foundation for differentiating instruction and learning (Tomlinson 2003). Researchers identified many significant understandings in helping to improve student learning. However, teachers often find it difficult to assimilate solid research findings into a coherent structure for classroom teaching and learning (Marshall, 2009). Most of the secondary school students are in concrete level, therefore, the teachers tried to link between concept and concrete experiences for probing misconceptions (Abraham, Williamson and Westbrook, 1994). The correction of misconceptions required direct experience. The new constructivist model proposed task based inquiry to develop link between concept and concrete experiences to encounter misconceptions.

Conceptual change model presented, "anomaly" as basic condition of accommodation (Posner, 1982). An anomaly existed when one was unable to assimilate something. Anomalies provided conflicts in cognition for an accommodation to the students. If teachers intended to prevent their students' misconceptions, they should develop a learning environment, where disequilibration occurred followed by accommodation (Piaget, 1964). How to develop anomaly among second language science students was a question of new dimension that could not be considered till now (Akram, 2014). The theoretical underpinning of the new model would be based on the process of equilibration of Piaget, with the modification of use of identified misconception for conceptual change. Identified misconceptions would transform into discrepant questions in producing the anomalies among second language science students for accommodation. Another important feature of conceptual change model is creating links otherwise; there is no difference between conceptual change and rote learning (Hewson, 1992). The new constructivist model not only intended to develop links between new and prior concepts but also tried to make connection between knowledge presented to the students in a second language and students developed misconceptions as a result.

Driver teaching model (1985) was based on constructivism, which gave students opportunity to make their own conceptions about a particular topic. Constructivist views of learning in science suggested that learners could only make sense of new situations in terms of their existing understanding. Learners used prior knowledge to interpret observations. Learners developed their concepts by adding to or modifying their existing ideas (Driver, 1985; Osborne, 1983). Osborne generative model (1983) gave premise that learners' prior knowledge might or might not be compatible with the new concept. The implications of such a view demanded teachers to find out the learners' ideas in order to consider these in their teaching. Teachers then needed to provide experiences that challenge the learners' existing understanding in order to help them restructure their ideas. Guidance was available on the ideas that learners held and on the range of methods, which researchers used to elicit the learners' ideas (Driver, 1985). However, the guidance available to teachers on how to promote restructuring of the learners' ideas was much more limited (Claxton, 1986; Trumper, 1990). The new proposed model would help to use identified misconceptions for restructuring the students' alternative ideas. Transformation of the identified misconceptions into anticipated questions and discrepant questions would help second language science students to assimilate and accommodate the new appropriate concepts. When students internalized new words in the presence of another knowledgeable person then they found themselves in the zone of proximal development (ZPD). It referred to the place for learning located somewhere between the student's present and latent understanding (Vygotsky, 1978). Students could understand the concepts consciously only when concepts were explained in a related context. The technical aspects of electrochemistry demanded the support of more knowledgeable person. The new proposed model would help second language science students to internalize the meaning of new words using language scaffolding with context in the presence of more knowledgeable peer or teacher.

Needham (1987) proposed constructivist model in his work 'Children Learning in Science Project'. It consisted on five phases namely the orientation, the generation of ideas, restructuring of ideas, application of ideas and lastly the reflection. The 5 E's (2009) was an instructional model based on the constructivist approach to learning. The 5 E's model allowed students and teachers to experience common activities, to use and build on prior knowledge and experience, to construct meaning and to continually assess their understanding of a concept. Keogh and Naylor (1993) mentioned a significant issue about how to make constructivism applicable to class, especially with 30 or even 40 or more students. Moreover, how the learner's ideas could be considered in planning suitable restructuring activities was a matter of concern (Keogh and Naylor, 1993; Claxton, 1986; Trumper, 1990). In principle, the suggestion that teachers should plan activities based on what the learners already know and understand looked like an obvious way to proceed. The problem arose with the sheer practicality of attempting to do that with a class of 40 or more learners. Even if the teacher has adequate information about the learners' initial ideas, attempting to respond to their individual ideas could become a difficult exercise in classroom management (Keogh and Naylor, 1993). The new proposed constructivist model would help teachers to experience considering students' ideas in manageable ways in a large class. It would facilitate teachers to make sense of how to work with a whole class.

A critical look at the status of science education in Pakistan revealed a dismaying situation, which was reflected in students' low achievement in core science subjects such as chemistry, biology, mathematics and physics, particularly at secondary level (Ali, 2013). The National Education Policies in Pakistan have considered quality science education in particular as a means to achieving radical social development (Government of Pakistan, 2009). The ultimate learning outcomes intended in the National Curriculum required from teachers to adopt a comprehensive vision of pedagogies and engage in practices premised on constructivist philosophy of learning that emphasized centrality of students in the learning process. How this happened in reality? Ali (2013) experienced alludes to a wide gulf that existed between the ideal goals and what actually happened in most of chemistry classrooms in Pakistan. Haider (2014) described the current situation of secondary schools in Pakistan i.e. teacher was active while students were just passive listeners in classrooms. The large size of the class created a distance between teacher and student. Ali (2013) concluded that social, contextual and cultural factors combined to affect students' ability to engage in science learning and their achievement in Pakistan.

Urdu is the national language of Pakistan whereas about 57 languages were reported to speak throughout the four major provinces of country (Khan, 2002). In Pakistan, academic courses such as mathematics and sciences were taught in English.

English is the second language or sometimes third language for all the students of Pakistan. When science students tried to understand the meanings of scientific concepts in a second language, they translated it into Urdu that developed misconceptions (Halai, 2007). The use of a second language as a language medium of instruction developed learning difficulties arising out of language barrier in Pakistan (Aziz et al., 2014). Moreover, Akram (2014) investigated language misunderstanding as an important factor of developing electrochemistry misconceptions among secondary school students of Pakistan. The high demands of conceptual learning required constructivist based teaching models to be implemented in science classes at Pakistan to letting go of transmission-oriented practices (Ali, 2013). The context of Pakistan with second language, large class size and passive role of learners demanded to improve the current constructivist models. Viewed against this background, the new constructivist model was needed to be developed for second language science students of Pakistan by using constructivist strategies in a manageable way in a large class to encounter misconceptions.

1.3 Statement of the Problem

Students' misconceptions in science considered as a major problem of concern to science educators, teachers and students. The researchers and teachers were interested to know the nature of misconceptions, the reasons behind these misconceptions and the effects of instruction to encounter the misconceptions (Ozmen, 2004). During learning, the students tried to connect new knowledge into their cognitive structure. If they held misconceptions, these misconceptions impeded their subsequent learning and misunderstanding of the concepts occurred (Nakhleh, 1992). Duit (2007) conducted a study on student's misconceptions in science and found that instruction often failed to engage the ideas that students brought to the classroom. Numerous researchers explored students' misconceptions in electrochemistry (Doymus, Karacop & Simsek, 2010; Garnett & Treagust, 1992a, 1992b; Nakhleh, 1992; Ogude & Bradley, 1994; Ozkaya, 2003; Sanger & Greenbowe, 1997a, 1997b). For the current study, topic of electrochemistry was selected because it was considered as a difficult topic for students to learn and for teachers to teach. Principles of electrochemistry had general applications used in routine e.g. electroplating. Moreover, the topic of electrolysis was common in physics and chemistry. Sometimes, it promoted confusion and students did not freely assimilate their knowledge across physics and chemistry. Student misconceptions were deeply rooted and extremely complex by a number of sources. Likewise, the student misconceptions often vary by geographical region, culture, religious background, gender and age (Losh, 2003). Barke (2009) suggested that every science teacher should know his own students' misconception. Wescott (2005) suggested that instructors should recognize the misconceptions of their own students as a first step in helping students confronting misconceptions.

In order to encounter students' misconceptions, it was essential to identify it and reasons behind it. The problem of misconception became more critical when science students had to acquire scientific concepts in second language. Electrochemistry misconceptions were reported previously among the learners who were learning chemistry in their first language, English (Garnett and Treagust, 1992; Sanger and Greenbowe, 1997a and 1997b; Ahtee, Asunta and Palm, 2002). While, in Pakistan and in many other developing countries, academic courses such as mathematics and sciences were taught in a second language. English is the second language or sometimes third language for all the students of Pakistan. Students misunderstood the language of instruction (second language) with their first language, Urdu that developed misconceptions in multilingual classrooms of Pakistan (Halai, 2007). Research studies indicated that students who study main courses in a second language had difficulty connecting new and old information meaningfully. For example, Johnstone and Selepeng (2001) concluded that second language science students lost at least 20 percent of their capacity to reason and understand. Morris (2008) emphasized on exploring the best possible sources behind students' diagnosed misconceptions in electrochemistry for future research. Mowshowitz, (2013) discussed the problems of terminology which develop language misunderstandings in science education. Improper visual presentation in the textbooks originated some electrochemistry misconceptions (Garnett & Treagust, 1992a, 1992b; Ozkaya, 2003). Students faced difficulties in understanding the abstract chemical processes especially at microscopic and symbolic levels. Sometimes, they overgeneralized prior knowledge in constructing the new concepts due to abstract natured chemistry topics (Garnett & Treagust, 1992; Lee & Arshad, 2009; Lin, 2002; Sanger & Greenbowe 1997a; Sanger & Greenbowe 1997b).

Although misconceptions in chemistry education had been established, yet their role during the learning process was poorly examined. How students develop misconceptions was still to be investigated (Hamza & Wickman, 2007). Further research was needed with context to use of second language for improving teaching and learning activities in electrochemistry by removing students' misconceptions. Clement (2008) examined the role of discrepant questioning in modification of cognitive conflict and accommodation. However, some issues needed to be investigated. For example, how to use identified misconceptions as anticipated and discrepant questions, how to develop disequilibrium state among second language science students for assimilation and accommodation. Constructivist theories recommended teachers to encourage their students in realizing their cognitive conflicts to change their misconceptions (Duit, 1991). Students could understand the concepts consciously only when concepts were explained in a related context. The technical aspects of electrochemistry demanded the support of more knowledgeable person. A comprehensive effort should be made to combine harmoniously the different teaching techniques used in various constructivist models for implementing manageably in large class with context to second language.

For this reason, it was aimed to encounter the students' electrochemistry misconceptions after identifying its reasons and develop a designed teaching sequence in the form of a new constructivist model. Moreover, the present study intended to make a logical connection between knowledge presented to students in a second language and their developed misconceptions as a result. Therefore, the present study was designed to develop a constructivist model to encounter the language misunderstandings, prior knowledge overgeneralizations and visualization errors for second language science students of secondary class in Pakistan.

1.4 Objectives of the Study

i. To identify the presence of electrochemistry misconceptions among second language science students of secondary class in Pakistan.
ii. To investigate the reasons behind the electrochemistry misconceptions among second language science students of secondary class in Pakistan.
iii. To develop constructivist model to encounter language misunderstandings, prior

knowledge overgeneralizations and visualization errors for second language science students of secondary class.

iv. To study the process of new proposed constructivist model to encounter electrochemistry misconceptions of second language science students in secondary class.

1.5 Proposed Research Questions

So present study was designed to seek the answers to the following questions

i. What electrochemistry misconceptions were identified among second language science students of secondary class in Pakistan?

ii. What were the reasons investigated behind the electrochemistry misconceptions among second language science students of secondary class in Pakistan?

iii. Was a new proposed constructivist model encountered language misunderstandings, prior knowledge overgeneralizations and visualization errors of second language science students of secondary class?

iv. How did new proposed constructivist model encounter electrochemistry misconceptions of second language science students in secondary class?

1.6 Conceptual Framework of the Study

This research work based on the principle that research in chemistry education might be strengthened in several ways when it was based on a theoretical perspective. Piaget (1950) emphasized on the modifications in the structure of prior knowledge. His theory suggested for development of tasks to engage learners. Ausubel (1968) suggested that teachers should discover what learners already know and then teach them accordingly. Vygotsky (1978) emphasized the role of social process in the process of concept formation. He suggested that new concepts appear first socially and then gradually became psychological. Scott, Asoko and Driver (1991) described a successful constructivist strategy based on building the correct prior knowledge. This theoretical perception provided a strong base in developing the new instructional model. The conceptual framework of the study was illustrated in Figure 1.2, which represented the use of constructivist approaches in developing an instructional model for meeting the misconceptions in the difficult topic of electrochemistry. The theoretical foundation of new model was consisted on two validated and reliable constructivist approaches of Piaget theory of equilibration and Vygotsky social constructivism.

1.6.1 Piaget Constructivist Approach

Piaget (1950) considered three important processes in cognitive development: assimilation, accommodation and equilibration. If learner used existing concepts to deal with new phenomena, this referred to assimilation. When existing concepts of learner were inadequate to grasp new phenomena, then he tried to restructure his central concepts. This status referred as accommodation. Equilibrium, determined the child's transition from one stage of development to the next. At the beginning, the learner used his logical structure that work well but toward the end of the stage, he became dissatisfied with his structure. This dissatisfaction developed disequilibrium state and it was essential for a new equilibrium. According to Piaget, equilibrium encompassed both assimilation and accommodation. Posner (1982) defined conceptual change in terms of assimilation and accommodation. Moreover, he stressed that there must be dissatisfaction with existing conceptions for conceptual change.

The theoretical underpinning of the new model was based on the process of equilibration of Piaget, with the modification of use of identified misconception. Here, identified misconceptions helped to produce disequilibrium state that lead to assimilation and accommodation.

1.6.2 Vygotsky Constructivist Approach

The dominance of language was a fundamental difference between Vygotsky view of conceptual development and that of Piaget. Piaget (1950) gave little attention to language and never assigned it a primary role in conceptual development. For Piaget, language was a mean of expressing thoughts that had already developed (Gredler, 1997). For Vygotsky, language role was central to the development of thought. He considered words as the means through which thinking developed. It was important to go beyond direct experience in teaching scientific concepts and to mediate experience with words (Howe, 1993). Vygotsky focused on process of conceptual development rather than product. His interest was how the students perform during different task situations.

Vygotsky (1962) believed that learning process occurred when students internalized the meanings of new words and after that; they became able to use them. When students internalized new words in the presence of another knowledgeable person then they found themselves in the zone of proximal development (ZPD). It referred to the place for learning located somewhere between the student's present and latent understanding (Vygotsky, 1978). Students could understand the concepts consciously only when concepts were explained in a related context using language (Vygotsky, 1978). The new model was based on theoretical underpinning of Vygotsky work. It believed that students could understand the scientific concept when it was explained in a related context. Moreover, the technical aspects of electrochemistry demanded the support of more knowledgeable person. The new proposed model would help second language science students to internalize the meaning of new words with ZPD and contextual communication.

Constructivist perspectives on learning had given rise to a number of instructional models e.g. Conceptual Change model, Driver teaching model, 5E Instructional model, Needham's Five-Phase Constructivist Model, Osborne Generative Model. Theses constructivist models facilitated the present study in developing a modified constructivist instructional model for confrontation of misconceptions with context to Pakistan. The context of Pakistan with second language, large class size and passive role of learners demanded to improve the current constructivist models.

The present research was conducted in two phases. First phase of the study was designed to develop the new constructivist instructional model after identifying the key electrochemistry misconceptions and its reasons among second language science students in secondary class at Pakistan. The cognitive and social constructivist learning approaches provided the theoretical foundation of new model. The new model developed the Double Triangular-ZPD chemistry education metaphor (Figure 1.2) for the current study. Double Triangular-ZPD chemistry education metaphor hybridized the triangle of macroscopic, microscopic, representational, with another triangle of misconceptions, context and language with the idea of ZPD. This metaphor believed that language scaffolding with three level of representation helped to encounter all the misconceptions identified due to language misunderstandings (L.M), prior knowledge overgeneralizations (P.K.O) and visualization errors (V.E). Moreover, a teacher might develop dissatisfaction among student's existing cognitive structure during instruction with context of identified misconceptions. It might help students to accommodate and assimilate the new appropriate concept in their minds instead of misconception. The detail of this metaphor was given with the explanation of new model in chapter 5.

During second phase, the process of new proposed constructivist model was studied to encounter language misunderstandings (L.M), prior knowledge overgeneralizations (P.K.O) and visualization errors (V.E) of second language science students in secondary class.

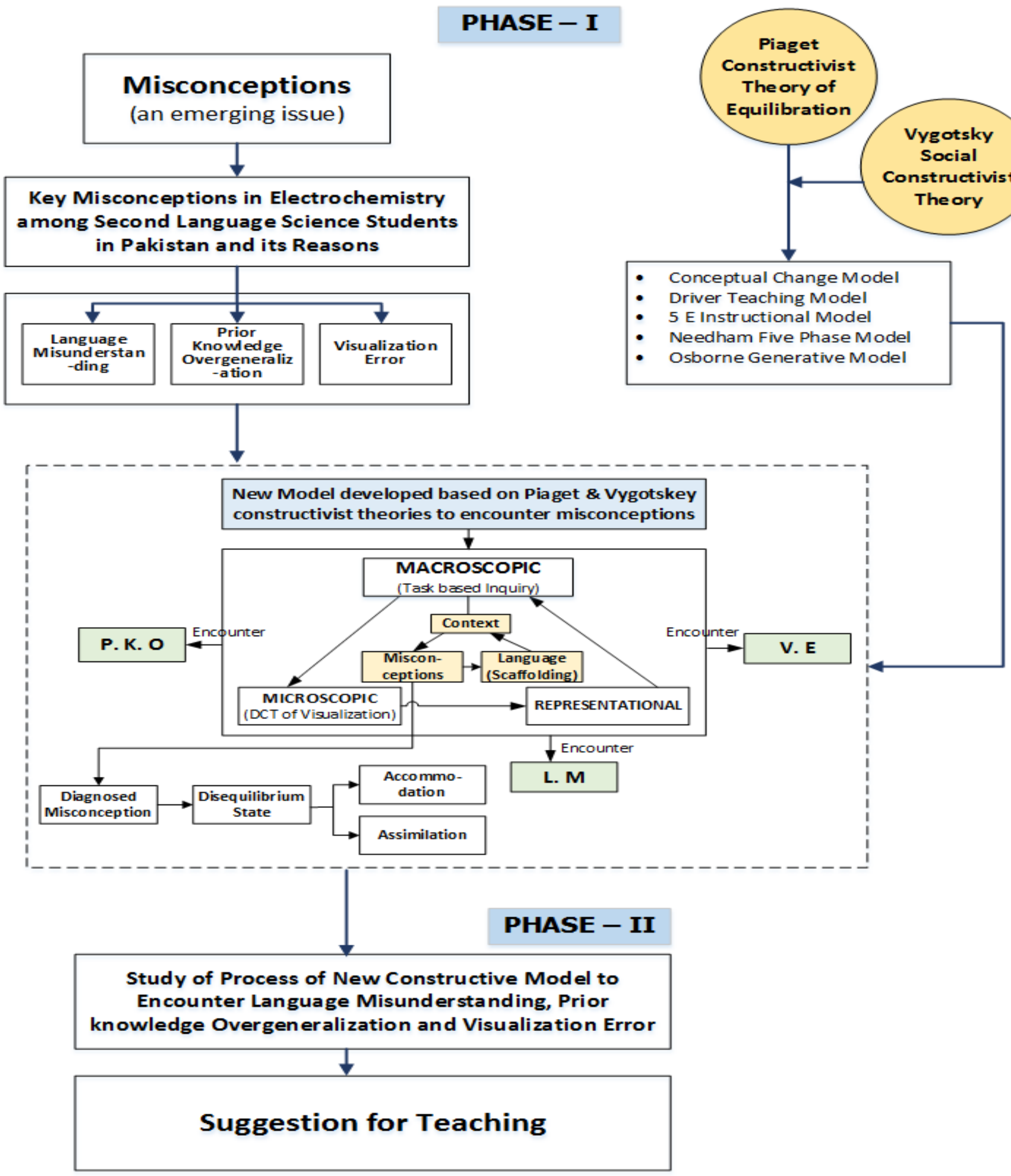

Figure 1.2 Conceptual Framework of the Study

1.7 Significance of the Study

Research in science teaching had indicated misconception implications on students learning outcomes and their learning process (Doymus, Karacop and Simsek, 2010; Garnett and Treagust, 1992; Ogude and Bradley, 1994; Ozkaya, 2002; Sanger and Greenbowe, 1997). The term misconception was different from mistakes, which can be recognized by the students themselves when presented with an accepted conception (Abimbola, 1988). Numerous research studies had shown that misconceptions concerning many aspects of chemical phenomena were prevalent among students (Cole and Todd, 2003; Hamza and Wickman, 2007). Concepts construction process of student could be diverted by misconceptions. For that, it was so important for teachers to know their students misconception. Barke (2009) suggested that every science teacher should know their students' misconception for his or her lessons.

Moreover, how students develop misconceptions and how they justify their non-scientific concepts or alternative conceptions were questions that still needed to be investigated (Hamza & Wickman, 2007). Schmidt (1997) raised the question for further researches that need to be investigated. The concerned question was, whether there were other concepts and terms that originated misconceptions in the complex concepts such as electrochemistry among students. How students develop misconceptions in using second language as medium of instruction, was a question of new dimension that could not be considered till now. The question, how students' misconception could be encountered with context of using second language and saturated classes were not given due consideration (Akram, 2014). Furthermore, Morris (2008) emphasized on exploring the best possible sources behind students' diagnosed misconceptions in electrochemistry for further research. Clement (2008) examined the role of discrepant questioning in modification of model element. However, the questions further needed to investigate i.e., how anticipated and discrepant questions helped to assimilate and accommodate the new appropriate concept in students' minds and how diagnosed misconceptions could be used as anticipated and discrepant questions.

Concept of electrochemistry had been reported among the most difficult concepts for secondary school students to learn and, for teachers and student teachers to teach and understand because of its abstract natured complex structure (Ogude and Bradley, 1996; Finley, Stewart and Yarroch, 1982; Butt and Smith, 1987; Ahtee, Asunta and Palm, 2002). Lee & Arshad (2009) reported some common misconceptions of students in learning electrochemistry. These were included as: (1) Students were always confused between the flow of current in the conductors and in the electrolytes. (2) They could not identify the anode and cathode or positive and negative terminal in the electrochemical cell. (3) They could not describe and explain the process happening at the anode and cathode. (4) They mixed up the oxidation and reduction process at the electrodes. (5) The concept of electrolyte was not clear to them.

Common assessment applied on these concepts could not explore misconceptions because students had never been assessed on their concept and scientific process understanding. There were several studies conducted to determine misconceptions about electrochemistry in the literature (e.g. Schmidt, 2007; Sanger and Greenbowe, 1997; Garnett and Treagust, 1992; Ozkaya, 2002; Hamza and Wickman, 2007). It was a need in teaching to focus on the topics in which students held misconceptions and that influenced their performance for future learning. There should be undertaken studies to find out learning obstacles and then to overcome these. Student-centered learning environments were enriched by effective methods and techniques, which are needed in order to help the students understand the challenging concepts. Some studies suggested ways of remedying electrochemistry misconceptions in the literature. These studies used different conceptual change method and techniques such as conceptual change instruction (e.g. Huddle, White and Rogers, 2000; Sanger and Greenbowe, 1997), cooperative learning strategies (Acar and Tarhan, 2007), conceptual change text (Yuruk, 2007) and jigsaw puzzle techniques (Doymus et al., 2010).

All of them pointed out that their conceptual change methods and techniques were effective in remedying students' misconceptions. However, they also reported that the techniques they used, could not completely overcome the student's electrochemistry misconceptions. In fact, this might stem from structure of conceptual change method or technique they used. That is, using just one teaching method to accomplish conceptual change might in fact result in some disadvantages (Ceyhun and Karagolge, 2005; Doymus, 2010). For example, students soon became bored with continued reading of conceptual change texts or use of jigsaw puzzle techniques (Doymus, 2010). To prevent such problems, using two or more methods or techniques or strategies, based on the constructivist theories, might help students to develop a better conceptual understanding.

The distinguished features of the present research showed the novelty of study. The present research proposed model that was developed based on validated and reliable cognitive constructivist approach (Piaget theory) and social constructivist approach (Vygotsky theory) of learning. This study focused on how students developed the electrochemistry misconceptions when they tried to construct their concepts in using the second language. Misconceptions were encountered in content of electrochemistry with context to present Pakistani situations (rote learning, saturated classes, misunderstanding of language and passive role of students). Diagnosed misconceptions were used to develop disequilibrium state among student's existing cognitive structure. Transformation of the diagnosed misconceptions into anticipated and discrepant questions helped students to assimilate and accommodate the new appropriate concept in their minds. Construction of knowledge was encouraged to attain through social negotiation keeping in view that there was no competition among students for recognition. After the concept formation, the concepts in the mind of learners were given a chance to reflect their knowledge through activities (quiz, presentations and discussions on thoughts and ideas). It will also provide feedback for teacher and learner. This model helped students to continually assess their understanding of a concept with the use of follow up and reflection activities.

It was hoped that this study grasped attention to the literature in the areas of learning, specifically, constructivism, challenging misconceptions, cognitive development and concept formation in second language. This study provided guidelines for teachers, at all levels, in diagnosing and encountering their own students' misconceptions. This study aimed to communicate the outcomes of research to teachers, textbook authors, college and university professors and teacher educators who involved in the preparation of science teachers. The favorable attitude towards self-construction of knowledge would be developed through this study. The outcomes of this study would steer the rudder towards amenable planning on the part of science teachers, science students, curriculum experts and policy makers. Moreover, the present study had the implications to various disciplines like teaching and learning of chemistry, curriculum development, students' assessment, reflection and modification in constructivist theories.

1.8 Delimitations of the Study

The present study was delimited to the secondary school students studying chemistry in a second language in government schools of Bahawalpur City. The study was also delimited to the topic, Electrochemistry, selected from the syllabus prescribed by the Punjab Text Book Board of Education for secondary class.

1.9 Definitions of Terms

The various terms used in this research study, were defined as following.

1.9.1 Concept

Concepts can be considered as ideas, objects or events that help us understand the world around us (Eggen and Kauchak, 2004). Concepts formed when the ideas or thoughts are developed based on common properties of objects or events by the process of abstraction (American Heritage Dictionary, 2002). Concepts are constructed as abstract objects. Concepts are created (named) to describe, explain and capture reality as it is known and understood. In this study, concept means ideas, thoughts or understanding of secondary school students about the abstract natured topic of electrochemistry.

1.9.2 Conceptual Difficulty

Difficulty or problems in pertaining to concepts or to the forming of concepts referred as conceptual difficulties. Duit (2007) described that students hesitate to answer the questions set on those concepts that are difficult for them. Student’s conceptual difficulties in chemistry created a major problem of concern to science educators, teachers and students (Ozmen, 2004). Electrochemistry regarded as one of the most difficult chemistry concepts in which both pre-service teachers and students have learning difficulties. In this study, conceptual difficulties mean difficulty or problems of secondary school students in constructing the concepts of electrochemistry.

1.9.3 Misconception

Misconceptions referred as students' mistaken answers to a particular situation or student's ideas, which cause mistaken answers about a particular situation or student's beliefs about how the world works different than that of the scientists (Dykstra, Boyle and Monarch, 1992). Misconceptions, on the other hand can be described as ideas that provide an incorrect understanding of such ideas, objects or events that are constructed based on a person's experience (Martin et al., 2002). The researchers used many labels for misconception such as "alternative frameworks", "alternative conceptions", "intuitive beliefs," and "native conceptions". In this study, the term misconceptions mean the incorrect understanding of electrochemistry concept that did not match to its proper scientific concept.

1.9.4 Constructivism

Learning that "is a process of constructing meaning; it is how people make sense of their experience" (Merriam, Caffarella, & Baumgartner, 2007). Historically, the term constructivism considered as a theory of learning. Whereas, during past few decades, constructivism started considering as a theory of teaching too with learning process. As a theory of learning, constructivism meant for knowledge construction. Phillips (2000), however, suggested that constructivism was not a theory of learning but a model of knowing. Elizabeth Murphy (1997) appealed that, concrete activities and use of real-world settings were the subjects associated with constructivist learning and teaching. In this study, the term constructivism considered as theory of teaching and learning process both. The present study used Piaget and Vygotsky constructivist theories.

1.9.5 Electrochemistry

Electrochemistry is the branch of physical chemistry that studies chemical reactions that take place at the interface of an electrode, usually a solid metal or a semiconductor and an ionic conductor, the electrolyte. These reactions involve electric charges moving between the electrodes and the electrolyte (or ionic species in a solution). Thus, electrochemistry deals with the interaction between electrical energy and chemical change. It is the study of chemical reactions, which produce electricity and how to use electricity to produce chemical reactions.

1.9.5.1 Electrochemical Cells

An electrochemical cell is a device that produces an electric current from energy released by a spontaneous or non-spontaneous redox reaction. It has two basic types, voltaic cell and electrolytic cell. The galvanic cell or voltaic cell, named after Luigi Galvani and Alessandro Volta, both scientists who conducted several experiments on chemical reactions and electric current during the late 18th century. The galvanic cell is an electrochemical cell in which a spontaneous chemical reaction takes place and generates electric current. The electrolytic cell is the type of electrochemical cell in which a non-spontaneous chemical reaction takes place when electric current is passed through the solution (Tariq and Chatha, 2012). In this study, electrochemical cells mean both galvanic cell and electrolytic cells.

1.9.5.2 Electrolysis

Electrolysis is the process of electrically inducing chemical changes in a conducting melt or solution e.g. splitting an ionic compound into the metal and non-metal (Tariq and Chatha, 2012). In this study, electrolysis means decomposition of an ionic compound in aqueous solution or in fused state by passing electric current.

1.9.5.3 Electrodes

Electrochemical cells have two conductive electrodes (the anode and the cathode). Electrodes can be made from any sufficiently conductive materials, such as metals, semiconductors, graphite and even conductive polymers. The anode is defined as the electrode where oxidation occurs and the cathode is the electrode where the reduction takes place. Anode is an electrode, through which electrons enter the external circuit. Cathode is an electrode through which electrons leave the external circuit. In this study, the electrodes mean anode and cathode.

1.9.5.4 Redox: Oxidation and Reduction Reaction

“Redox” is a combination of “reduction” and “oxidation”. The word oxidation originally implied reaction with oxygen to form an oxide. Later, the term was expanded to encompass oxygen-like substances that accomplished parallel chemical reactions. Ultimately, the meaning was generalized to include all processes involving loss of electrons. The word reduction originally referred to the loss in weight upon heating a metallic ore such as a metal oxide to extract the metal. In other words ore was "reduced" to metal. Antoine Lavoisier (1743–1794) showed that this loss of weight was due to the loss of oxygen as a gas. Later, scientists realized that the metal atom gains electrons in this process. The meaning of reduction then generalized to include all processes involving gain of electrons. Redox reactions include all chemical reactions in which atoms have their oxidation state changed; in general, redox reactions involve the transfer of electrons between species (Prescott, 2001).

In this study, the term redox means reduction and oxidation. Oxidation means a chemical reaction in which oxygen is added or hydrogen is removed or electrons are lost. Reduction is a chemical reaction in which oxygen is removed, hydrogen is added or electrons are absorbed.

1.9.6 Discrepant Question

A discrepant question is one designed to produce dissatisfaction with a student’s model or conception (Clement, 2008). Discrepant questions go beyond simply providing students with cues to convey content elements. Cotton’s definition (1988) implied that the discrepant questioning is suggesting to the student what to pay attention to, what is important in the teacher’s view and what directions to follow in learning the information. The discrepant question may actually stimulate the students in constructing the information in the form of a workable and runnable model. In this study, the discrepant questions mean questions designed in the topic of electrochemistry to produce dissatisfaction with students’ misconception for accommodation.

1.9.7 Student

A student (also pupil) has its dictionary meaning as a learner or who attends an educational institution. In this study, students mean secondary school students studying chemistry in government schools in a second language. The present study dealt with the topic of electrochemistry that is present in IX class. Hence, all those second language science students were selected for phase-I who have studied this topic.

1.9.8 Teachers

The term teacher possessed its dictionary meaning and referred as a person who teaches or instructs or communicate. Someone whose job is to teach in a school or college or any educational institution. In this study, teachers mean chemistry teachers (both male and female) who were teaching electrochemistry to IX class in government secondary schools.

1.9.9 Language

The term language referred as a systematic means of communicating ideas or feelings by the use of conventionalized signs, sounds, gestures or marks having understood meanings. Language plays an active role in the development of scientific ideas. A concept is not fully realized or understood until it is represented in language. From Vygotsky's perspective, learning is viewed as a profoundly social process. Dialogue with the teacher and peers plays crucial role in learning. For Vygotsky, language was central to the development of thought; words were the means through which thought was formed. It is important to go beyond direct experience in teaching scientific concepts and to mediate experience with words; experience alone is not enough since the experience is an isolated observation unless it is put into words and understood in a larger context. In this study, language means use of second language in science teaching generally and teaching electrochemistry particularly.

1.10 Summary

Chemistry is the compulsory subject for all secondary school students of science group in Pakistan. The pass percentage in the subject of chemistry is very low i.e. about 50 %. Students' misconceptions in chemistry were found a major problem of concern to science educators, teachers and students. The researchers were interested to know the nature of misconceptions, the source of these misconceptions and the effects of instruction on elimination of misconceptions. In order to diffuse student's misconceptions, the first step was to identify the misconceptions and its reasons. Then teachers might be able to encounter these misconceptions. Usually students felt problem in understanding the complex phenomena of chemistry, like oxidation and reduction reactions and electrolysis. Although different teaching strategies had been used, yet chemistry students continue to hold their misconceptions.

Electrochemistry misconceptions were reported previously among the learners who were learning chemistry in their first language English. While, in Pakistan, academic courses such as mathematics and sciences were taught in a second language. The problem of misconception became worse when science students had to acquire scientific concepts in second language.

There were different validated and reliable teaching models based on constructivist learning approaches. The use of constructivist teaching and learning models would help teachers to enhance students' learning by removing the misconceptions in electrochemistry. The current constructivist models needed to modify with context to Pakistani situation i.e. use of second language for instruction, saturated classes and passive role of students. Hence, present study aimed to develop a constructivist model to encounter electrochemistry misconceptions after identifying the misconceptions and its reasons among second language science students in secondary class.

REFERENCES

Abimbola, I. O. (1988). The problem of terminology in the study of student conceptions in science. *Science Education*, 72(2):175–184. Retrieved on March 10, 2015, from DOI: 10.1002/sce.3730720206.

Abraham, M. R., Williamson, V. M. and Westbrook, S. L. (1994). A cross-age study of the understanding of five concepts. *Journal of Research in Science Teaching*, 31(2), 147-165.

Acar, B. and Tarhan, L. (2006). Effect of cooperative learning strategies on students' understanding of concepts in electrochemistry. *International Journal of Science and Mathematics Education*, 5, 349-373.

Aggarwal, J.C. (2007). *Essentials of Educational Technology.* (7th ed.) New Delhi: Vikas Publications House.

Ahtee, M., Asunta, T. and Palm, H. (2002). Student teachers' problem in teaching electrolysis with a key demonstration. *Chemistry Education: Research and Practice in Europe*, *3*(3), 317-327. Retrieved on February 27, 2015, from http://dx.doi.org/10.1039/b0rp90031a.

Akku, H., Kadayıfçı, H., Atasoy, B. and Geban, O. (2003). Effectiveness of instruction based on the constructivist approach on understanding chemical equilibrium concepts. *Research in Science and Technological Education*, 21(2), 209-227.

Akram, M., Surif, J. B. and Ali, M. (2014). Conceptual Difficulties of Secondary School Students in Electrochemistry. *Asian Social Science*, 10(19), 276–281.

Ali, T. (2013). *A Case Study of the Common Difficulties Experienced by High School Students in Chemistry Classroom in Gilgit-Baltistan (Pakistan).* Sage Publication:DOI:10.1177/2158244012447299, http://www.sagepublications.com

Al-balushi, S. M., Ambusaidi, A. K., Al-shuaili, A. H. and Taylor, N. (2012). *Omani twelfth grade students, most common misconceptions in chemistry,* 23(3), 221–240.

Almquist, A.J. and Cronin, J.E. (1988). Fact, fancy and myth of human evolution. *Current Anthropology,* 29, 520-522.

Arons, A.B. (1990). *A Guide to Introductory Physics Teaching*. (2nd ed.) New York:

John Wiley & Sons.

Arizona State University (June 2001). Student Preconceptions and Misconceptions in Chemistry. *Integrated Physics and Chemistry Modeling Workshop,* America: ASU.

Ausubel, D.P. (1968). *Educational Psychology*: A Cognitive View. New York: Holt, Rinehart and Winston.

Aziz et al., (2014). Learning Difficulties and Strategies of Students at Higher Secondary Schools in Punjab, *Journal of Policy Research*, 1(2), 55-61. http://rfh.org.pk/jur/magazine-category/jpr

Bain, B. and Yu, A. (1980). Cognitive consequences of raising children bilingually: One parent, one language. *Canadian Journal of Psychology*, 34, 304-313.

Barke, H. D., Strehle, N.,Roelleke, R. D. (2007). *Ion im Chemieunterricht – noch Vorstellungen von gestern?* MNU 60, 366.

Barke et al. (2009). *Misconceptions in Chemistry*. Berlin Heidelberg: Springer-Verlag

Barufaldi, J. (2005) Based on the 5E Instructional Model. *Science Collaborative Conference in Austin,* July, 2005. Cornel University Texas, 20-36.

Bernhard, J. (2000). Improving Engineering Physics Teaching - Learning From Physics Education Research. *Physics Teaching in Engineering Education*, Budapest,

BetulEkiz, E. (2011). Pre-Service Chemistry Teacher's Understanding of Electrolytic Cell. *Journal OF Chemistry Education,* 125-132.

Bird, E. and Welford, G. (1995). The effect of language on the performance of second-language students in science examinations. *International Journal of Science Education,* 17(3), 389-397.

Bomide, G. (1985) Science teaching in a period the recession: the need for improvisation. *Journal of Science Teachers Association of Nigeria* 23, 1and2, 34-38.

Bruner, J. (1990) *Acts of Meaning,* Cambridge, MA: Harvard University Press.

Caprio, M. W. (1994). Easing into constructivism, connecting meaningful learning with student experience. *Journal of College Science Teaching*, 23(4), 210-212.

Carey, S., Evans, R., Honda, M., Jay E. and Unger, C. (1989). An experiment is when you try it and see if it works: a study of grade seven students' understanding of the construction of scientific knowledge. *International Journal of Science Education*, 11, 514-529.

Cassels, J. R. T. and Johnstone, A. H. (1983). Meaning of the words and the teaching in chemistry. *Education in Chemistry*, 20, 10–11.

Cassels, J.R.T. and Johnstone, A.H. (1985). Words That Matter in Science. London:

Royal Society of Chemistry, 75, 22-27.

Ceyhun, I. and Karagolge, Z. (2005). Chemistry students' misconceptions in electrochemistry. *Australian Journal of Education Chemistry*, 65, 24-28.

Charmaz, K. (2006). *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*, London: Sage Publications

Clement, J.J and Rea-Ramirez, M.A. (2008), *Model Based Learning and Instruction in Science*, 195–213. Springer.

Collier, V. P. (1995). Acquiring a Second Language for School. *Directions in Language & Education National Clearinghouse for Bilingual Education*. 1, 4.

Collier, V. P. (1989). How long? A synthesis of research on academic achievement in a second language, *TESOL Quarterly*, (23), 509-531.

Cotton, K. (1988). *Monitoring student learning in the classroom*. Portland: Northwest Regional Educational Laboratory.

Comins, N. F. (1993). Sources of Misconceptions in Astronomy. *Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics*, NY: Cornell University, 1-38.

Creswell, J. W. (1994). *Research designs: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage.

Creswell, J.W. (2007). *Qualitative inquiry and research design: Choosing among various approaches* (2nd ed.). Thousand Oaks, CA: Sage. (2007).

Creswell, J. W. and Clark, V. L. (2007). *Designing and conducting mixed methods research.* Thousand Oaks, CA: Sage.

Creswell, J. W. and Creswell, J. W. (2013). *Steps in Conducting a Scholarly Mixed Methods Study.* Thousand Oaks, CA: Sage

Creswell, J. W. (2009). *Research Design Qualitative, Quantitative and Mixed Methods Approaches*. USA: Sage.

Claxton, G. (1986) The alternative conceivers' conceptions. *Studies in Science Education*, 13, 123-130

Dawson C.J. (1978), Pupils difficulties: what can the teacher do? *Journal of Education in Chemistry.* 15, (4).

De Bruin, G. P. (2004). Problems with the factor analysis of items: Solutions based on item response theory and item parcelling. *SA Journal of Industrial Psychology*, *30*(4), 16–26. doi:10.4102/sajip.v30i4.172

Doymus, K., Karacop, A. and Simsek, U. (2010). Effects of jigsaw and animation techniques on students' understanding of concepts and subjects in electrochemistry. *Educational Technology Research and Development*, 58(6), 671–691.

Driscoll, M. P. (1994). *Psychology of Learning for Instruction*. Allyn and Bacon: A Division of Paramount Publishing, Inc.

Driver, R., Guesnes, E. and Tiberghien, A. (1985). *Some Features of Children's Ideas and their Implications for Teaching.* Retrieved June 5, 2009, from http://www.ipn.uni-kiel.de/aktuell/stcse/

Duit, R. (2007). *Students' and teachers' conceptions and science education.* Retrieved June 5, 2009, from http://www.ipn.uni-kiel.de/aktuell/stcse/

Finley, F. N. Stewart, J. and Yarroch, W. L. (1982). Teachers' perceptions of important and difficult science content. *Science Education*, 66, 531-538.

Gabel, D. L., (1999). Improving Teaching and Learning Through Chemistry Education Research: A Lock to the Future, *Journal of Chemical Education*, 76(4), 548-554.

Garnett, P. J., Garnett, P. J. and Treagust, D. F. (1990). Implications of research on students' understanding of electrochemistry for improving science curricula and classroom practice. *International Journal of Science Education*, 12, 147–156.

Garnett, P.J. and Treagust, D. F. (1992a). Conceptual difficulties experienced by senior high school students of electrochemistry: Electric circuits and oxidation-reduction equations. *Journal of Research in Science Teaching*, 29(2), 121–142.

Garnett, P. J. and Treagust, D. F. (1992b). Conceptual difficulties experienced by senior high school students of electrochemistry: Electrochemical (galvanic) and electrolytic cells. *Journal of Research in Science Teaching*, 29(10), 1079-1099.

Garnett, P. J. and Treagust, D. F. (1992). Conceptual difficulties experienced by senior high school students of electrochemistry: Electric circuits and oxidation-reduction equations. *Journal of Research in Science Teaching*, *29*(2), 1079-1099. Retrieved February 27, 2014 from http://dx.doi.org/10.1002/tea.3660291006.

Gay, L. R. (2000). *Educational Research* (5th ed.). Competencies for Analysis and Application. USA: Merril Publishing Co.

Gilbert, J. K. (2007). Visualization: a Metacognitive Skill in Science and Science Education. In John K. Gilbert (ed.), *Visualization in Science Education.* Dordrecht: Springer. 9-27.

Gilbert, J. K. (2008). Visualization: an emergent field of practice and enquiry in Science Education. In J. K. Gilbert, M. Reiner, M. Nakhleh (Eds.), *Visualization: Theory and Practice in Science Education.* UK: Springer. 3-24.

Goodman, N. and Elgin, C. Z. (1988). *Reconceptions in philosophy and other arts and sciences*. Indianapolis: Hackett.

Government of Pakistan (2009). *National Curriculum for General Science.* Islamabad: Ministry of Education.

Gravetter, J. F. and Wallnau, B. L. (2004). *Statistics for the Behavioral Sciences*. (6 th ed.) USA: Thomson Learning.

Gray, A. (2011). *Constructivist Teaching and Learning*. SSTA Research Centre 97-07:25. Retrieved on February 27, 2014 from file:///D:/muz%20constructivism/97-07. htm#What%20is%20.

Gredler, M. E. (1997). *Learning and instruction: Theory into practice*. New Jersey: Prentice Hall.

Griffiths, A. K. (1994). A critical analysis and synthesis of research on students' chemistry misconceptions. In H.-J. Schmidt (Ed.), Proceeding of the International Seminar at Dortmund University. Prob- lem Solving and Misconceptions in Chemistry and Physics. Hong Kong: ICASE, p. 70.

Groves, et.al. (2004). *Survey methodology. Handbook*, NJ: John Wiley and Sons.

Haider, G. (2014). An Exploratory Study of Organizational Problems Faced by Pakistani Student Writers with Learning Difficulties (LD) in EFL Writing. *International Journals of English and Education,* 3(1), 127-145.

Halloun, I.A. and Hestenes, D. (1985). The initial knowledge state of college physics students. *American Journal of Physics*, 53(11), 1043-1055

Halai, A. (2007). Learning mathematics in English medium classrooms in Pakistan: Implications for policy and practice. *Bulletin of Education and Research*, 29(1), 1-15.

Hamza, K. M. and Wickman, P.-O. (2007). Describing and analyzing learning in action: An empirical study of the importance of misconceptions in learning science. *Science Education*, 92(1), 141–164.

Hewson, P.W. and Hewson, M. G. A. B. (1992). The conditions of conceptual change in the classroom, *International Journal of Science Education 11 (special issue),* 541-53.

Howe, A. C. and Durr, B. (1982). Using concrete materials and peer interaction to enhance learning in chemistry. *Journal of Research in Science Teaching,* 19, 225-232.

Howe, A. C. (1993). A Vygotskian Perspective on Teaching for Conceptual Change. In

The Proceedings of the *Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust*: Ithaca, NY.

Huddle, P. A, White, M. D. and F. Rogers. (2000). Using a teaching model to correct known Conceptual Difficulties in electrochemistry. *Journal of Chemical Education (JCE)* Vol. 77 (1): 104 – 110.

Integrated Physics and Chemistry Modeling Workshop (2001). *Student Preconceptions and Misconceptions in Chemistry*. Arizona State University (ASU). America

Johnstone, A. H. and Selepeng, D. (2001). A Language Problem Re-visited, Chemistry Education: *Research and Practice in Europe* (CERAPIE), 2(1), 19-29.

Karsli, F. and Calik, M. (2012). Can Freshman Science Student Teachers' Alternative Conceptions of "Electrochemical Cells" Be Fully Diminished? *Asian Journal of Chemistry*, 24 (2), 485-491.

Kessler, C. and Quinn, M. (1980). Bilingualism and science problem-solving ability, Bilingual Education Paper Series, *Evaluation Dissemination and Assessment Center, California State University,* Los Angeles: 4 (1).

Keogh, B. and Naylor, S. (1993). Learning in science: another way in. *Primary Science Review*, 26, 22-23.

Khan, A. R. (2002). *Language and content: A case study of how science is taught in a community - run private English medium school in Karachi Pakistan*. Master's Thesis Ontario Institute for studies in education of the University of Toronto, Canada.

Kikas, E. (2004). Teachers' conceptions and misconceptions concerning three natural phenomena. *Journal of Research in Science Teaching (JRST)*. 41(5): 432–448.

Kocakulah, S, Ustunluonglu, E. and Kocakulah, A. (2005). The effect of teaching in native and foreign language on students' conceptual understanding in science courses. Asis- Pacific Forum on Science Learning and Teaching, 6 (2), 1-30.

Kvale S., (1996), *Interviews*, Thousand Oaks: Sage Publications.

Lafferty, P. and Rowe, J. (eds.) (1994), *The Hutchinson Dictionary of Science*, revised edition, London: Helicon.

Langer, J. and Applebee, A. N. (1987). *How writing shapes thinking: A study of teaching and learning.* National Council of Teachers of English.

Laporte, R. (1998). *Pakistan. World book Multimedia Encyclopedia*. CD Rom Chicago, IL: World Book Inc.

Lee, T. T. and Mohammad Yusof Arshad. (2009). Miskonsepsi Pelajar Tingkatan Empat Mengenai Elektrokimia. *Jurnal Sains dan Matematik UPSI*, Vol.1, No.2, pp. 52-64.

Lin, H.S., Yang T.C., Chiu, H.L. and Chou, C.Y. (2002). Students' Difficulties in Learning Electrochemistry. *Proc. Natl. Sci. Council*. ROC (D), Vol.12, No.3, pp. 100–105.

Losh, S.C., Travani, C.M., Njoroge, R., Wilke, R. and McAuley, M. (2003). What does education really do? Educational dimensions and pseudoscience support in American general public, 1979-2001. *Skeptic Inquirer* 27, 30-36.

Marshall, J. C. (2007). *4E × 2 Instructional Model: Promoting stronger teaching and deeper conceptual understanding.* Paper presented at the School Science and Mathematics Association, Indianapolis, IN.

Mayer, R. E. (2008). Learning and Instruction. (2nd ed.). Upper Saddle River, NJ: Pearson Education.

Merriam, S. B., Caffarella, R. S. and Baumgartner, L. M. (2007). *Learning in Adulthood: A Comprehensive Guide* (3rd Ed.). San Francisco, CA: Jossey-Bass.

Millar, R. and Driver, R. (1987). Beyond Processes. *Studies in Science Education*, 14, 33-62.

Mowshowitz, D. (2013) Advanced Problems in Introductory Courses: Some Sample Problems and Why they Work. *Biochemistry & Molecular Biology Education (BAMBED)* 34, No 2: 134–138.

Murphy, E. (1997). *Characteristics of Constructivist Teaching and Learning.* Constructivism: from Philosophy to Practice. Retrieved on February 27, 2014 from http://www.cdli.ca/~elmurphy/emurphy/cle.html

Nakhleh, M. B. (1992). Why some students don't learn chemistry: Chemical misconceptions. *Journal of Chemical Education*, *69*(3), 191-196.

Needham, R. and Hill, P. (1987). *Teaching Strategies for Developing Understanding in Science.* UK: University of Leeds.

Niaz, M. (2002). Facilitating conceptual change in students' understanding of electrochemistry. *International Journal of Science Education*, 24, 425-439.

Niaz, M. and Chacon, E. (2003). A conceptual change teaching strategy to facilitate high school students' understanding of electrochemistry. *Journal of Science Education and Technology*, *12*(2), 129-134. Retrieved on February 27, 2015 from http://dx.doi.org/10.1023/A:1023983626388

Obomanu, B. J. (2012). Students Conceptual Difficulties in Electrochemistry in Senior

Secondary Schools, *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS).* 3(1), 99–102.

Ogude, A. N. and Bradley, J. D. (1994). Ionic conduction and electrical neutrality in operating electrochemical cells. *Journal of Chemical Education, 71*(1), 29-34.

Osborne, R. and Gilbert, J. (1980). A method for investigating concept understanding in science. *European Journal of Science Education*, 2, 311–321.

Osborne, R. and Wittrock, M.C. (1983). Learning science: A generative process. *Science Education*, 67, 489-508.

Ozkaya, A.R. (2002). Conceptual difficulties experience by prospective teachers in electrochemistry: half-cell potential, cell potential and chemical and electrochemical equilibrium in galvanic cells. *Journal of Chemical Education*, 79(6), 735-738.

Ozkaya, A. R., Uce, M., Saricayir, H. and Sahin, M. (2006). Effectiveness of a conceptual change-oriented teaching strategy to improve students 'understanding of galvanic cells. *Journal of Chemical Education, 83*(11), 1719-1723. Retrieved on February 20, 2015, from http://dx.doi.org/10.1021/ed083p1719

Ozkaya, A. R., Uce, M., Saricayir, H. and Sahin, M. (2003). Education, M. (2003). Prospective teachers' conceptual understanding of electrochemistry : Galvanic and electrolytic cells. *The Royal Society of Chemistry.*, 1–12.

Ozmen, H. (2004). Some student Conceptual Difficulties in chemistry: A literature review of chemical bonding. *Journal of Science Education and Technology, 13*, 147-159.

Pardhan H. and Bano Y. (2001). Science teachers' alternate conceptions about direct currents. *International Journal of Science Education*. 23, 301

Palmer, D. (2005). A Motivational View of Constructivist Informed Teaching. *International Journal of Science Education*. 27(15).

Park, O.C. and Hopkins, R. (1993). Instructional conditions for using dynamic visual displays: A review. *Instructional Science*, 21, 427-449.

Patton, M. Q. (2002). *Qualitative research and Evaluation Methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Phillips D. (2000). *Constructivism in Education.* Chicago: University of Chicago Press.

Phillips, D. C. and Burbules, N. C. (2000). *Postpositivism and Education Research*. Lanham, MD: Rowman and Littlefield.

Piaget, J. (1950). *The Psychology of Intelligence*. New York: Harcout, Brace.

Posner, G.J., Strike, K. A., Hewson, P. W. and Gertzog, W. A. (1982). Accommodations of a scientific conception: toward theory of conceptual change. *Science Education*, 66(2), 211-227.

Pollnick, M. and Rutherford, M. (1993). The use of a conceptual change model and mixed language strategy for remediating misconceptions in air pressure. *International Journal of Science Education*, 15, 363-381.

Prescott, C. N. (2001). *Chemistry* (6 th ed.) Singapore: Federal Publications Pre Ltd.

Prince, Michael and Felder, R. (2007). Inductive teaching and learning methods: Definitions, comparisons and research bases. *Journal of Engineering Education* 95, (2): 123-38.

Prince, M., Vigeant, M. and Nottis, K. (2012). Using inquiry-based activities to repair student misconceptions related to Heat, energy and temperature. *Frontiers in Education Conference Proceedings*, 2012, 1–5. doi:10.1109/FIE.2012.6462344

Rosenblatt, L. M. (1978). *The reader the text the poem: The transactional theory of the literary work*. Carbondale: Southern Illinois University Press.

Richardson, V. (2003). *Constructivist Pedagogy*. Columbia: Teachers College Record, 105(9), 1623- 1640.

Sia, D.T., Treagust, D.F and Chandrasegaran, A.L. (2012). High School Chemistry Students 'Proficiency and Confidence Levels in displaying their Understanding of basic Electrolysis Concepts. *Journal of Science and Mathematics Education,* 1325-1345.

Sileshi and Barke, H.D. (2007). Chemistry Misconceptions: Evaluating Remedies Based on Tetrahedral-ZPD Metaphor. *3rd Symposium of Chemistry Education,* 2007, University of Muenster, Muenster,

Skelly, K. M. and Hall, D. (1993). The development and validation of a categorization of sources of misconceptions in chemistry. *Third International Seminar on Misconceptions and Educational Strategies in science and Mathematics*, August, 2009. Ithaca,

Sanger, M. J. and Greenbowe, T. J. (1997a). Students' Conceptual Difficulties in electrochemistry: current flow in electrolyte solutions and the salt bridge. *Journal of Chemical Education*, *74*(7), 819-823. Retrieved on February 27, 2013 from http://dx.doi.org/10.1021/ed074p819

Sanger, M. J. and Greenbowe, T. J. (1997b). Common student Conceptual Difficulties in electrochemistry: Galvanic, electrolytic and concentration cells. *Journal of*

Research in Science Teaching, 34(4), 377-398. Retrieved February 27, 2013 from http://dx.doi.org/10.1002/(SICI)1098-2736(199704)

Schmidt, H., Marohn, A. and Harrison, A.G. (2007). Factors that prevent learning in electrochemistry. *Journal of Research in Science Teaching,* 44, 258-283.

Schmidt, H.-J. (1997). Students' Misconceptions, Looking for a pattern. Science Education,81(2),123–135.doi:10.1002/(SICI)1098-237X(199704)81:2< 123::AID-SCE1>3.0.CO;2-H

Slavin, R. E. (1988). *Educational psychology: Theory into practice*. Englewood Cliffs: Prentice Hall.

Steffe, P. L. and Gale, J. (1995). *Constructivism in Education*. New Jersey: Lawrence Erlbaum Associates, Inc. and Future, 235–240. Dordrecht: Kluwer.

Strauss, A. and Corbin, J. (1998). *Basics of Qualitative Research* (2nd ed). London: Sage

Swain, M. and Lapkin, S. (1981). *Bilingual education in Ontario: A decade of research*. Toronto: Ministry of Education.

Taber, K.S. (2002). Alternative conceptions in Chemistry: prevention, diagnosis and cure. *The Royal Society of Chemistry*. London.

Tariq, J. and Chatha, I. A. (2012). *Punjab Text Book of Chemistry*. (1st ed.) Lahore: Caravan book House.

Teichert, M. A. and Stacy, A. M. (2002). Promoting understanding of chemical bonding and spontaneity through student explanation and integration of ideas. *Journal of Research in Science Teaching.* 39, 464–496.

Thompson, J. and Soyibo, K. (2002). Effects of lecture, teacher demonstrations, discussion and practical work on 10th graders attitudes to chemistry and understanding of electrolysis. *Research in Science and Technological Education*, 20, 25-37.

Thompson, P. (2000). *Radical constructivism: Reflections and directions*. In L. P. Steffe and P.W. Thompson (Eds.). London: Falmer Press.

Tomlinson, C. A. (2003). *Fulfilling the promise of the differentiated classroom: Strategies and tools for responsive teaching.* Alexandria, VA: ASCD.

Trumper, R. (1990). Being constructive: an alternative approach to the teaching of the energy concept. *International Journal of Science Education*, 12 , (4), 343-354.

Tynjala, P. (1998). Traditional studying for examination versus constructivist learning tasks: do learning outcomes differ? *Studies in Higher Education*, 23(2), 173-190.

Wandersee, J. H., Mintzes, J. J. and Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning.* New York: Macmillan. 177–210.

Wescott, D. J., & Cunningham, D. L. (2005). Recognizing Student Misconceptions about Science and Evolution. *Mountain Rise*, 2, 1-8.

Vavra, K. L., et. al. (2011). Visualization in Science Education, *ASEJ,* 41(1).

Vygotsky, L. S. (1962). *Thought and Language*, Cambridge, MA: MIT Press

Vygotsky, L.S. (1978). *Mind and Society, the Development of Higher Mental Processes*. Cambridge: Harvard University Press.

Yardley, L. (2008). *Demonstrating validity in qualitative research*. *Qualitative psychology: a practical guide to research methods,*. London: Sage.

Yang, E.-M. andre, T. and Greenbowe, T. J. (2003). Spatial ability and the impact of visualization/animation on learning electrochemistry. *International Journal of Science Education*, 25, 329-349.