A Case Study of the Common Difficulties Experienced by High School Students in Chemistry Classroom in Gilgit-Baltistan (Pakistan)

Takbir Ali

Abstract
This article reports a research study conducted with four chemistry teachers in three high schools (two government schools and one private school) in Gilgit-Baltistan region of Pakistan. The study investigated questions concerning common difficulties high school (Grades 9 and 10) students experience in chemistry classroom, the possible reasons for these difficulties, and the ways in which teachers help students overcome these difficulties. A qualitative case study method was used to investigate the questions, which used in-depth interviews with teachers, classroom observation, and postobservation discussion with the teachers, as main data collection tools. The key findings of the study allude to a huge gap between what is intended in the National Curriculum in terms of students’ learning in chemistry and what actually happens in the classroom where students learn chemistry. Promoting in-depth learning appeared to be an uphill task for the teachers. The main hurdle lies in students’ inability to demonstrate a good understanding of very basic concepts of the subject. Despite faced with such a challenge, the teachers appear to be committed to teaching their subject. The implications of the results of the study are explained in the context of schools, teachers, and other educational stakeholders by emphasizing the need for synchronization and integration of efforts on the part of schools.

Keywords
National Curriculum, high school chemistry, in-depth learning, common conceptual difficulties

The Socioeconomic Context
Gilgit-Baltistan, most recently known as Northern Areas, is a partially self-governing territory under Pakistani control. It forms parts of Pakistan’s international borders with China to the northeast, Afghanistan to the northwest, and Indian- and Pakistan-administered Kashmir to the southeast.

In the last census (1998), the population of Gilgit-Baltistan was 870,347. The population is growing with the rate of 2.8% and, according to a recent estimation, the population has approached 1 million (Government of Pakistan, 2010).

Despite some positive socioeconomic changes, the region remains one of the most disadvantaged in Pakistan. The geographical isolation, hard climatic conditions, mountainous environment, and scarcity of resources contribute to the region’s continuing socioeconomic backwardness. People have very limited access to essential facilities such as health care, education, communication, electricity, and transportation. Most people (90%) live in sparsely scattered remote villages. The annual per capita income is estimated at 60% of the national standard of US$1,047 (Government of Pakistan, 2009a). The communities depend for their livelihood on a variety of sources such as substance farming, employment with government and private sector organizations, and limited commercial activities (e.g., trade with China, tourism, retailing, transport, and running restaurants). The major source of livelihood, however, remains subsistence farming of wheat, corn, barely, vegetables, fruits, and cattle. Marketing of fresh and dried fruits such as apple, pear, cherries, apricot, almond, and walnut contributes to families’ income (The Aga Khan Rural Support Program, 2000).

The education indicators for Gilgit-Baltistan Pakistan fall below the national average, and the quality of education in the region is inferior to that of the rest of Pakistan (The Aga Khan Development Network [AKDN], 2001). The adult literacy rates are 64% for males and 34% for females (Government of Pakistan, 2010). The gross school enrolment

1Aga Khan University, Karachi, Pakistan
and literacy rates, particularly the level of participation in middle and secondary education, vary substantially from place to place within the region, both rates being generally lower for women (AKDN, 2001).

The most widely recognized challenge to school improvement in Gilgit-Baltistan comes from deeply entrenched instructional practices that make students memorize a great deal of information with the limited purpose of reproducing it in the Board Examinations (The Aga Khan Education Service, 2005; The Aga Khan Foundation, 1998; Shafa, 2003; World Bank, 2004). The Aga Khan Education Service (2005) noted, “Teaching methods are teacher-centered and do not encourage student participation. Rote memorization and moral dictates go hand in hand with a punitive school environment” (p. 24). It further points out that the quality of education is particularly low in the rural areas because schools have insufficient material resources and staff, and teachers are either untrained or poorly trained. The report also says that most teachers have little exposure to English and few opportunities to practice it and that, in many cases, teachers have inadequate content knowledge, particularly in mathematics and science.

**Background of the Study**

The National Education Policies in Pakistan including the recent one (Government of Pakistan, 2009b) have considered quality education in general and science education in particular as a means to achieving radical social development. The Government of Pakistan (2009b) stressed that comprehensive social development can be achieved by developing a strong base of workforces that is equipped with cutting edge scientific and technological knowledge and skills. By and large, the education system in the country has failed to ensure provision of quality and purposeful science education for the young generation. This failure is mainly attributed to such factors as irrelevant science curriculum, school milieu, and classroom practices to ignite the interest of students and inculcate in them positive attitude toward science. A critical look at the status of science education in Pakistan reveals a dismaying situation, which is reflected in students’ low achievement in core science subjects such as chemistry, biology, mathematics, and physics, particularly at secondary level, which is a critical stage for students to decide about their field of study after Grade 10. Chemistry is taught as a compulsory subject to Grades 9 and 10 students who opt for science as their main field of study at secondary level in high school in Gilgit-Baltistan. The chemistry curriculum prescribed for secondary classes (Grades 10 and 12) contains a wide spectrum of concepts pertaining to organic, inorganic, and physical chemistry that are to be learnt and mastered by the students in a 2-year period. Nation Chemistry Curriculum of 2006 for Grades 9 and 10 is a well-constructed document. The aims and objectives are comprehensive and well articulated, and standards and benchmarks are well defined and aligned appropriately with aims and objectives. The National Chemistry Curriculum states:

“Chemistry Curriculum builds on the vertical progression of the K-VIII science curriculum. It offers a relatively in-depth study of chemistry as a major, independent science. It focuses on content, process skill, problem solving, inquiry, and critical and analytical thinking skills . . . The aim of the curriculum is to produce students who will be capable of doing independent thinking, asking questions, and looking for answers on their own. (p. 01)

The curriculum is based on three broad categories of activities that define the critical abilities of scientifically literate students in Pakistan. These are knowing and using science knowledge (learning science), constructing new science knowledge (doing science), and reflecting on science knowledge (thinking science). These broad performance indicators are connected with standards and benchmarks that describe what knowledge and skills students should acquire in the subject. These standards emphasize “higher order thing,” “deep knowledge,” “substantive knowledge,” and “connection to the world beyond the grade room” (Government of Pakistan, 2006, p. 04).

The ultimate learning outcomes intended in the National Curriculum are quite ambitious, requiring teachers to adopt a comprehensive vision of pedagogies and engage in practices premised on constructivist philosophy of learning that emphasizes centrality of students in the learning process. How this happens in reality? My experiences allude to a wide gulf that exists between the ideal curricular goals and what actually happens in most of chemistry classrooms in Pakistan in general and in rural Gilgit-Baltistan in particular.

The spiral science curriculum followed in schools in Pakistan includes a wide range of concepts; the number of concepts and knowledge around these concepts grow complex with change of class (Grades 1-10). Like the curricula of social sciences, the school curriculum of natural science are also subject to criticism. The most common criticism of the schools’ science curricula is that the curricula are not necessarily designed by taking into account the research in the field of cognitive science and educational psychology. This pitfall in the process of the development of curriculum has resulted in a large gap between curricular learning targets and level of students’ cognitive abilities; some of these abilities develop with age. So the curriculum prescribed for various grades is not pitched at the actual cognitive capacity of different grade students to acquire and process knowledge (Iqbal & Shayer, 1995, 2000). In a study in Pakistan, Iqbal and Shayer (1995) found visible gaps in between-curricular demands and cognitive levels of middle grade students (aged 11-13). The researcher, using the developmental stages proposed by the Jean Piaget as reference points, investigated the
relationship between curriculum demands and the cognitive levels of Grades 6 to 8 students. The researchers found visible gaps between the demands of middle grades science curriculum and cognitive levels of students. The researchers concluded, “It becomes evident that there exists a gap—which becomes increasingly wider—between curricular demand and the cognitive levels of middle school students” (p. 48). This made it difficult for teachers to teach the curriculum for understanding, and as a result, students were forced to learn by rote. The teachers also need to adapt curriculum to students’ level of cognitions and experiences by adjusting modifying instructions, adjusting materials, and designing tasks to engage students in process-based learning, and employing motivational techniques to increase students’ interest, confidence, and competence in science at secondary level.

Most of the children who study chemistry at the secondary level are not satisfied with their experiences of learning, in schools in general and public system schools in particular. As mentioned above, curriculum standards emphasize acquisition of specialized knowledge that needs certain attitudes, frame of mind, and skills on the part of students. Teaching of chemistry in government as well as in private schools in Gilgit-Baltistan contributes little to attainment of the critical knowledge, skills, and attitudes envisaged in the National Curriculum document. Resultantly, students find it difficult to engage in in-depth learning of content knowledge in chemistry. With a weak foundation, students even after passing Secondary School Certificate (SSC) examination fail to make any strong connection with the subject. According to Iqbal, Azam, and Rana (2009), “The traditional approach starts from predetermined body of knowledge . . . The traditional way of teaching science is strictly based on textbooks and teacher is believed to be a dispenser of knowledge” (pp. 5-6).

Based on my experiences and my reflections as a learner, as teacher, and lately as a teacher, I developed interest in the kind of research I have reported in this article. The experiences I gained working with students and teachers in government schools in different parts of Pakistan are reminiscent of my early experiences as a student. I recall how much time and effort I needed to put into memorizing factual information from textbook. Teacher would force us to memorize subject matter in chemistry (definitions, theories, principles, chemical equations, etc.) merely to be able to recall this information in the examination. I found my perceptions about teaching and learning developed during student life influencing my practices as a teacher. Gradually, exposition to new experiences that came through formal training and ongoing reflections, my perceptions about teaching and learning science changed. I began to believe that there is no real value in learning scientific knowledge through memorization; learning subject matter knowledge in science is powerful after going through certain cognitive processes such as constructing hypothesis, test hypothesis, classifying information, controlling variables, making predictions, carrying out practical activities, doing observation, recording and analyzing data, and making sense of the data. Until and unless a learner practices or undergoes some of these cognitive process in the science classroom, gaining conceptual understanding into science concepts remains a utopian dream for majority of students. Students’ transition into secondary science curriculum without having command over knowledge of subject matter in middle-level science curriculum becomes really a challenge for the students as well as for the teachers. As a result, majority of students in high school struggles with their science subjects, particularly chemistry course. More than 50% students would require to retake their examination in the chemistry course. Even the students who pass the course usually do not gain desired depth in understanding the knowledge of subject matter. There has been a lack of systematic and in-depth investigation into the situations and issues that surround teaching and learning of chemistry in high school in Gilgit-Baltistan. Research studies are needed to better understand the problems as well as the possibilities of improving teaching chemistry in high schools in Gilgit-Baltistan and Pakistan at large.

Literature Review

Researchers around the world have examined a wide range of issues and practices in chemistry classrooms from various angles. The findings from this body of research suggest ways for improving teaching chemistry at the secondary level. However, research studies conducted in chemistry classroom at the secondary level, both in Pakistani and international context, have predominantly focused on identifying students’ misconceptions around a wide range of chemistry concepts. Typically, the studies, interested in students’ misconceptions, have used different diagnostic tools, such as test instrument, checklist, and so on, or conducting diagnostic interviews with students or with teachers, to elicit their misconceptions and its origin. There have been hardly any efforts on the part of researchers interested in misconception to situate them in the social context of the classroom. Studies of conceptual difficulties in chemistry more often than not take place within an environment created by the researcher to serve the specific purpose of his or her study.

The complexity of classroom life is important to be considered because students and teachers are expected to collaborate on every aspect of classroom life involving teachers relating to students and students relating to each other through various ways such as discussion, debating, and communicating ideas. The complex interaction between teacher and students and among students constitutes the social context of classroom environment where teachers and students are engaged in a collective process of learning that produces shared understanding and generates new knowledge or perspectives and helps students take responsibility of their own learning (e.g., Brown & Campione, 1996; Tahir & Treagust, 1999). This requires teachers to balance the tensions
and discrepancies between students' ideas and scientific knowledge, and ensure that classroom activities are geared toward in-depth understanding of important science ideas and practices (Crawford, Kelley, & Brown, 2000). This underscores the need for investigating students' tensions and difficulties by situating them in the social context of the classroom where teachers and students are engaged in collective process of constructing knowledge of scientific phenomena.

Moreover, secondary-level chemistry course requires significant prerequisite knowledge and understanding of very basic concepts. The researchers showing interest in students' or teachers' misconception have predominantly focused on eliciting a sophisticated understanding of advanced-level content and thereby “taking for granted” the common difficulties that arise from the lack of understanding of a range of very basic concepts and terms that are commonly used in chemistry classroom as a base to understand advanced-level scientific knowledge. It is therefore pertinent to ask as how students, particularly students in rural settings, such as Gilgit-Baltistan, where a variety of general and context-specific challenges paint a poor picture of teaching and learning science, grapple with such basic concepts in chemistry classroom. The issues and challenges students confront at various levels are complex and may not be grasped only through using diagnostic test instruments; rather, they can be captured in a more comprehensive way by studying them as they occur in the complex social environment of the classroom during routine teaching.

“Misconception research” has produced a great deal of knowledge about misconceptions or alternative frameworks that hamper students’ in-depth learning of concepts in chemistry. A large number of studies in international context as well as in Pakistan have investigated students’ misconception around a wide range of concepts in secondary chemistry. Some of these concepts are atoms and molecules (e.g., Griffiths & Preston, 1992; Harrison & De Jong, 2005; Teichert, Tien, Anthony, & Rickey, 2008); gases and related concepts such as temperature, pressure, kinetic molecular theory, diffusion (e.g., Benson, Wittrock, & Baur, 1993; Krnel, Watson, & Glazar, 1998); chemical bonding (e.g., Coll & Taylor, 2001; Frailich, Kesner, & Hofstein, 2009; Othman, Treagust, & Chandrasegaran, 2008); solution, solubility, and solubility equilibrium (e.g., Ebenezer & Erickson, 1996; Pinarbası & Canpolat, 2003; Raviolo, 2001); electrochemistry and related concepts (e.g., Coll & Treagust, 2003; Sanger & Greenbowe, 1997; Taber, 1997); structure and properties of molecular and ionic compounds (e.g., Butts & Smith, 1987); particle theory (Johnson, 1998a, 1998b; Mursaleen, 1999); chemical equilibrium (e.g., Banerjee, 1991); acids and bases (e.g., Drehslcer & Schmidt, 2005; Hand, 1989; Lin & Chiu, 2007; Nakhleh, 1994; Schmidt, 1995).

The studies cited above have revealed several misconceptions or alternative conceptions that serve as barriers to in-depth learning of concepts in chemistry. Some of these studies have also investigated the origins of these misconceptions (e.g., Bano, 1998; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Harrison & Treagust, 2002; Krnel et al., 1998; Syed, 2003; Wandersee, Mintzes, & Novak, 1994). A common but a key finding that cuts across the lessons learnt in these studies is about the students’ lack of understanding of the Particulate Theory because almost every concept in chemistry depends on the particulate nature of matter, which lays the foundation for understanding of other concepts (Harrison & Treagust, 2002). As noted by Taber (1997), many students’ problems in chemistry lie in not understanding the relation between the molecular and macroscopic representations because students have not grasped the role of models in chemistry. Students' misconceptions regarding these concepts are based on the fact that they live and operate within macroscopic world of matter and do not easily follow shifts between macroscopic and submacroscopic levels. Consequently, they tend to develop alternative conceptions and nonscientific mental models. Adding to the problem is the fact that the teachers tend to consider the particulate nature of matter as one of the simpler topics to be dealt with quickly at the beginning of the year.

To sum up, as indicated by the above-cited studies, students generally do not understand the fundamental ideas of the Particulate Theory. Misunderstanding of basic ideas relating to the Particulate Theory pervades other concepts, as it serves to establish an alternative conception in students’ minds that causes them to misunderstand further content knowledge in chemistry presented to them. Much of research in science education has capitalized on the work of cognitive psychologists. Learning in science is viewed as a highly complex cognitive activity. Researchers have explored the effect of diverse cognitive and personality characteristic on children’s learning science. However, the pioneering work done by cognitive psychologists, Piaget and Vygotsky, the two renowned cognitive psychologists, have made significant contribution to learning science. In fact, their theories provided a conceptual base to constructivism, one of the major contemporary theory of learning. Central to Piaget’s cognitive constructivism and Vygotsky’s social constructivism is the emphasis on the role of social world in the cognitive development of a child. Despite their agreement on the inseparable nature of the relationships between individual and the environment, the two cognitive psychologists differ in the way in which they conceive the role of social world and the individual. According to Piaget (1977, cited in Atherton, 2011), the development of the child is a result of an adaptation to the social and the physical milieu. Social life is a necessary condition for the development of logic (Piaget, 1977, cited in Wood, 1998). Vygotsky built his theory on the premise that individual intellectual or cognitive development can be better understood with reference to the social milieu in which social support in the form of interaction with others that also involve skills, which have developed in a
sociohistorical context, mediate intellectual activity. Thus, individual development, from Vygotsky’s point of view, becomes a high mental process that cannot be understood within the context of social interactions.

Yet another type of research within the genre of research in science education is attitude based or attitudinal research. The attitudinal research is based on the premise that students’ meaningful engagement in learning science is primarily determined by their level of motivation and positive attitudes and optimism towards the subject (Osborne, Simon, & Collins, 2011; Rogoff, 2006). The attitude-based research studies conducted in Pakistan (e.g., Anwar & Bhutta, 2010; Iqbal et al., 2008, 2009; Iqbal, Nageen, & Pell, 2008) and elsewhere in the world (e.g., Foley & McPhee, 2008; Haussler & Hoffmann, 2003) typically have focused on students’ attitudes toward learning science. In the attitude-based research, the main focus has been on perceptions, experiences, emotions, thoughts, opinions, enthusiasm, likes and dislikes, and so on. In the attitudinal research, researchers have used a variety of variables as units for attitude analysis such as age level or study grades, gender, social context, rural and urban sites, and so on. Overview of the various finding from attitudinal research literature can be summarized into three interrelated broad or general principles: first, students’ attitude toward science is an important determinant of how students relate to the subject that in turn influences how they learn science; second, students’ attitude toward science is shaped by numerous factors from the sociocultural environment in which students live and undergo social experiences which in turn influence students’ cognitive or intellectual abilities; and third, positive attitude towards science are inherently linked with their social and life experiences and thereby students’ level of success in learning science is attributed to the level of motivation they bring to learning the subject. These principles, emanating from attitudinal research, have important implications for efforts toward improving science education. These principles are further briefly examined with the help from the researcher literature.

Iqbal et al. (2008), using an attitude scale used by researchers in the United Kingdom (Pell & Jarvis, 2001, cited in Iqbal et al., 2008), explored primary and elementary school (Grades 4-8) children’s attitude toward science, with particular interest to see if there was a difference in the level of the effect of Islamic values on students’ attitude compared with the British secular societal values. The study used students’ gender and schools’ locations (urban and semiurban context) as important units of analysis. The findings suggested that despite many sociocultural differences, no significant variations in predetermined attitude indicators were found in the Pakistani and the British study. Pakistani children, both from urban and semiurban locations, seemed to be in accord with their peers in British schools who considered exploratory and discovery-based learning as means to effective learning in science. The overarching conclusion of the study is that despite the acute lack of resources for science education in schools, boys and girls both from urban and semiurban schools hold positive views about learning science. Children in semiurban environment bring positive attitude toward science despite the fact that they do not get opportunity in schools to do experimentation. The researchers infer, “experimental approach to science is attractive to children regardless of gender and geographical locations” (Iqbal et al., 2008, p. 281). It is interesting to note that children from semiurban context displayed more positive attitude toward becoming scientists compared with their peers in urban schools. This, according to the researchers, is due to the fact that parents reinforce the perception among children that in underprivileged rural or semiurban context getting education in the field of science is an easy way to finding reasonable employment and improving living conditions. Pakistani studies (e.g., Anwar & Bhutta, 2010; Iqbal et al., 2008) are not in accord with international studies that have reported the role of sex as being the most influential variable related toward children’s attitudes to science. Boys have consistently shown positive attitude towards science than girls, although both Pakistan studies did not see any significant influence of gender on students’ attitude toward science.

Research in science education has established that students’ level of success in learning science is inherently linked with their positive attitude toward science that in turn is attributed to the level of motivation they bring to learning the subject. Research has revealed that students’ motivation in science learning plays a pivotal role in promoting conceptual change and engaging in deep and reflective thinking, which are instrumental in enhancing students’ science achievement. This suggests that stimulating students’ motivation to learn science becomes an intervention on the part of teachers. Research in Pakistan and other countries on the role of focused intervention in improving students’ learning outcomes in science have found positive correlation between the two. The implication of attitude-based research is that teachers are not merely to focus on modifying their own classroom practices rather they have to play a role in changing the conditions in the inextricably entwined contexts of classroom, school, home, and the larger society. A study by Iqbal and Shayer (2000) investigated the impact of a 2-year intervention program undertaken to accelerate students’ cognitive development in selected public and private secondary schools in Pakistan. The intervention program, tested previously in a research study in the United Kingdom, involved teacher training and visit of experts to selected schools sites to provide on-the-spot guidance to teachers regarding conducting lessons. To assess students’ level of cognitive development, pre- and posttests were conducted using the Piagetian test. The analysis of the data showed notable differences in the performance of students from control and experimental schools; the intervention seemed to have visible impact on students’ cognitive development manifested by their ability to construct meaning, engaging in metacognition and logical reasoning. All these cognitive skills are
critically important for learning science with understanding. The researchers concluded that factors such as quality of the input (teacher skills and attitude), school philosophy, and general cultural of the schools came to play to determine the overall impact of the intervention.

Efforts on the part on individual teacher or schools to improve secondary students’ learning outcomes in science need to be cognizant of the complex nature of the learning in science. In-depth learning of science is influenced by multiple interactive factors. To understand the impact of contextual factors on learning science, it is necessary to examine the circumstances around teaching and learning of science and the meaning given to these by teachers and schools as well as by parents and community members. Teachers and school, trying to improve students’ learning outcomes in science, find themselves confined within a set of conditions that may support or hinder effective learning in science. By creating those conditions that support effective learning, teachers, managers, and parents can enhance the opportunity for academic improvement to become a permanent part of the school and the classroom environment. Those conditions that hamper improvement in teaching and learning processes, if remain unrecognized, lead to failure despite all efforts on part of teachers and school.

Method

The Participants of the Study

This study involved four secondary school teachers (three male, one female), teaching chemistry at the secondary level, who were selected through purposive sampling process, coming from three high schools (two associated with government and one belonging to a private, not-for-profit school system) characterized by their relatively good reputation for imparting quality science education at the secondary level. To study science, students from other neighboring elementary or high schools would take admission in the sampled schools. The four participants drawn from these schools were selected as a representative of those surveyed in purposive sampling process, and all displayed a high level of commitment towards teaching their subject. The selection criteria considered to include chemistry teachers in the sample who had at least 5 years of experience in teaching chemistry and were interested in improving their teaching methods and modifying and adjusting their instruction for the purpose of improved students’ learning in chemistry. The information that helped to identify the schools and the teachers within these schools was collected through visiting schools and district offices, meeting with headteachers, teachers and students, district officials, and reading through documents such as examination results.

Through written application, I obtained administrative consent from competent authorities of the schools and from the participants. I provided the authorities and the participants with detailed information about my study: the purpose of the study, its intended benefits, sampling criteria, the demands on teachers’ time, the timeline of the study, data collection tools and procedure, and assurance of confidentiality and anonymity.

I did not directly interact with students. However, I observed them learning chemistry in the classroom. In this way, they become secondary participants in my study.

I observed teaching and learning process in three different classrooms having students in chemistry class ranging from 30 to 40 students. So, on average, I could collect data about 100 students’ learning chemistry during routine lessons in the classroom.

As articulated above, primarily the study is not concerned with exploration of students’ misconception around certain topics in chemistry; rather it aims to create a context for discussion and reflection on common issues, tensions, and challenges faced by students in chemistry classroom in high schools in Gilgit-Baltistan. The underlying purpose is simply to gain a better contextualized understanding into how the rhetoric of change (engaging students in variety of processes to foster scientific thinking and cognitive development) reflected in the National Curriculum interacts with the realities of practice in the context of students’ learning of chemistry in high schools in Gilgit-Baltistan.

I employed qualitative case study method to generate relevant data in the study. The case study method helped in collecting rich qualitative data about classroom processes such as instructions, teacher–student interaction, students’ encounter with knowledge of subject matter, and teachers’ pedagogical tactics. Multiple data collection tools, such as in-depth interviews, classroom observations, and postobservation reflective discussion with the teachers were used to gathered qualitative data. Classroom observations helped document activities and processes, critical incidences, and anecdotal evidence about students’ difficulties in learning concepts and teacher’s pedagogical moves to remedy these difficulties. The postobservation reflective discussion with the teachers and in-depth interview with the research participants helped access the participants’ experiences, beliefs, and values that underpin their teaching practices. To facilitate in-depth interviews with individual participants, open-ended questions were used that allowed further probing.

The teachers were interviewed for about an hour regarding their teaching of chemistry in general and about teaching primary concepts in particular. They were asked to reflect on the instructional strategies, instructional materials, classroom activities, and home tasks, catering to individual students’ learning needs. The interviews were recorded on audio cassettes and were transcribed and analyzed.

I observed five routine lessons (35- to 40-min long instruction time) of each teacher. The purpose of the observations was to examine in depth how the teachers organize activities around the topic under consideration, what challenges confronted students in in-depth learning of subject...
matter, and how the teachers helped them in the learning process and improved students’ understanding of the subject matter.

The in-depth interviews with teachers, classroom observations, and postobservation reflective discussions with teachers were guided mainly by the following general questions:

- What common difficulties do students experience during routine chemistry lessons?
- What are the possible reasons for these difficulties?
- How do teachers, in their day-to-day teaching, help students overcome these difficulties?

Data Analysis

The above three questions represent together a framework for collection and analysis of data provided. The data analysis was guided by three main categories: (a) teachers’ experiences about conceptual learning of subject matter; (b) the issues, tensions, and challenges associated with in-depth learning of basic chemistry concepts; and (c) the manner in which teachers assist students to overcome conceptual difficulties and tensions.

Based on the above categories, content analysis (Miles & Huberman, 1994) was carried out, which involved reading and rereading of transcripts, identification of small key ideas, and grouping and regrouping these ideas into key themes. The key themes were compared across the four cases to identify cross-cutting key themes. The broad cross-cutting themes were formulated into key findings, which were further analyzed and interpreted to reach plausible conclusions.

Findings

Analysis of the data collected through classroom observation, postobservation reflective discussion, and in-depth interviews with the teachers helped identify certain critical incidences and anecdotal evidences that explain the common difficulties faced by students in chemistry classrooms, the causes underlying these difficulties, and teachers’ responses to these difficulties. Triangulation of data from three different sources helped identify key cross-cutting themes. These themes are translated into the following key findings.

First, there is a huge gap between what is intended in the National Curriculum and what actually happens in the classroom where students learn chemistry. The realities of practice suggest that for chemistry teachers, fostering in-depth learning in line with and in the true spirit of the aims and objectives of the National Curriculum is a task easier said than done. Realization of such curricular goals as development of higher order thinking, knowing and using scientific knowledge, and constructing new science knowledge remains a utopian dream in high school in Gilgit-Baltistan.

Second, there are multiple reasons contributing to students’ failure to engage in meaningful learning in chemistry classrooms. However, the main hurdle lies in students’ inability to demonstrate a good understanding of very basic concepts of the subject. Due to huge gaps in students’ understanding of fundamental concepts, they are unable to engage in in-depth learning of advanced level content. This finding accords with the lessons reported by other studies that emphasize the inherent link between students’ prior knowledge and new knowledge (e.g., Gollub, Bertenthal, Labov, & Curtis, 2002; Mayhill & Brackley, 2004; Perkins, 1993).

Third, despite working against all odds, the teachers appear to be committed to teaching their subject. They do try to assist students to overcome the difficulties in their effort to make a good sense of the subject matter presented to them. The teachers do make deliberate efforts to value and explore students’ prior knowledge and use it as a basis to help students construct an understanding of concepts under consideration. They do try out their own unique remedial tactics and instructional strategies to engage students in meaningful learning. These strategies include using examples, analogies, questioning, cues and probing, and prompting; offering alternative explanation; supplying information to fill knowledge gaps; reinforcing key points; and backtracking. Backtracking, however, remains a dominant instructional strategy the teachers use to bridge the gaps that existed between students’ prior knowledge and the content knowledge under consideration. These pedagogical tactics are very much grounded in the teachers’ personal experiences as learners and resulting intuitive understandings of ways through which to help students grasp concepts by constructing their own meaning and making connections.

The teachers are familiar with the variety of challenges faced by students in in-depth learning of subject matter. They demonstrate awareness about the ways through which to address these challenges or at least mitigate the adverse effect of these challenges on students’ learning. Akram Khan (pseudonyms), for example, reflects on such a challenge and his approach to dealing with it. He says,

In my view, Periodic Table of elements is the backbone of chemistry. Understanding of the chemistry is contingent upon understanding of the Periodic Table. Had I been the author of this book [Chemistry], I would have kept the Periodic Table as the first chapter. In chemistry, the Periodic Table should be taught first. Students’ learning about concepts such as valency is dependent on their understanding of the concepts of “Groups” and “Periods” [in the Periodic Table]. I would say children who understand the Periodic Table well can easily grasp the whole subject. (Excerpt from teacher’s interview)

Afzal Ali (pseudonyms), another participant, makes similar observations when he says,

The textbook defines the concept of valency as “the ability of an element to combine with another element
to form a compound.” This is vague, and that is why it takes us three days to make children understand the concept of valency. We need to emphasize a deeper knowledge of Periodic Table first. (Excerpt from teacher’s interview)

Here the teachers criticize the chemistry textbooks because their sequencing of chapters and topics lacks internal logic and coherence. The Periodic Table provides very basic information about the characteristics of the elements. Therefore, their suggestion of resequencing textbook’s chapters and shifting the Periodic Table from Chapter 3 to Chapter 1 may make a sense.

Furthermore, the teachers consider learning as a developmental process in which earlier experiences provide the foundations for making sense of later ones. They believe that their students can construct knowledge through an interaction between what they know already and the new learning they experience. Nargis Bano (pseudonyms), for example, considers linking students’ prior understanding to a new concept as central to promoting conceptual learning. She argues, “If students’ prior understanding of a concept is probed in-depth and breadth, it helps a great deal in fostering deeper understanding of the subject matter” (excerpt from teacher’s interview). Muhammad Basheer (pseudonyms) also echoes Nargis Bano’s emphasis on prior knowledge when he says, “For me it is highly desirable to consider how can I make connections between new learning and prior learning and how those connections can variously support or confound students’ acquisition of new understanding” (excerpt from teacher’s interview).

Arguing in a similar vein, Afzal Ali (pseudonyms) says, “Students possess a quite complex structure of ideas and experiences; and, if motivated and provided with proper help, they can gain deep understanding through interactions between new knowledge and previous knowledge of the concept” (excerpt from teacher’s interview). Akram Khan holds similar views about building students’ understanding of subject matter on what they already know about the concept. For example, reflecting on one of his instructional decisions during a chemistry lesson, he explains:

The task I assigned to student was a little bit challenging because I believe that students possess the abilities for doing everything. If we provide them with opportunities they can do it [learn on their own]. Children carry with them a rich collection of ideas and information. The only thing they need is guidance. (Excerpt from postobservation discussion)

In the above, the teachers’ reflections underscore the need for valuing students’ ideas, conceptions, opinions, experiences, and knowledge and linking them with a new knowledge or experiences.

The Situations Revealing Students’ Tensions and Difficulties

Students’ tensions and difficulties were manifested by the close observation of the following situations in the classroom: when the teacher introduced a new concept in a lesson and students could not cope with it; a lesson involving more advance-level information pertaining to the subject matter under consideration; students recalling factual information (word to word) instead of describing the ideas, information, or meaning in their own words; students’ inability to linking ideas or making conceptual connections; students’ not offering explanation in support of their viewpoint; and students not asking question. All these situations were recognized by the triangulation of data from my field notes (classroom observation), teachers’ interviews, and teachers’ reflection on anecdotes and critical incidences.

Classroom Anecdotes and Critical Incidences

Example I (Atomic model/structure). In one of the chemistry lessons, Akram Khan was teaching chemical equation, but given the situation he needed to revisit the atomic model. The students confused the definition of atomic number with mass number, position, and characteristics of atomic particles in the atom with each other (e.g., associating negativity with proton and positivity with electron). Primarily, the difficulty in gaining in-depth understanding of the concept of atomic model seems to be embedded in the complex and abstract nature of the concept, as noted by many studies concerned with the particulate theory of matter. The teacher explained by using diagram of atomic model (labeling and describing parts of atom) and did backtracking (recalling information previously learnt).

Example II (Ionic bonding). A lesson dealt with formation of the ionic compound calcium chloride (CaCl₂). Students thought that in CaCl₂, Ca²⁺ combined with 2Cl⁻. The misconception lied in the fact that Cl⁻ + Cl⁻ = 2Cl⁻ instead of conceiving it as Cl⁻ + Cl⁻ = 2Cl⁻. Students were also confused that why Ca²⁺ + (Cl⁻ + Cl⁻) is written as CaCl₂ why not 2CaCl. The teacher verbally explained the law of definite proportion and showed on the blackboard how it applied to the example at hand: Ca carries two plus charges (Ca²⁺), whereas Cl carries one minus charge. So to form ionic bond between Ca and Cl, two atoms of Cl are required. The total charge on Cl atoms taking part in the reaction will be −2.

Example III (Chemical equations). In one of the lessons involving chemical equations, students could not easily deal with the question of balancing chemical equation, and second could not explain to the teacher as why did they write 2 with H on the left-hand side and 2 with H₂O on the right-hand side of the equation, that is, 2H₂ + O₂ = 2H₂O and 2Na + Cl₂ = 2NaCl. In fact, the teacher was preparing students for
a lesson about chemical bonds. The lesson began with teacher’s question: “Who can tell me chemical formula of water?” Two students (29 students were present in the class) kept quiet, the rest raised their hands, indicating that they knew the answer. The teacher chose one student to answer the question. Students correctly recalled the answer (H₂O). Teacher posed second question: “Who can describe for me how water (H₂O) forms?” This time the number of raised hands decreased (23 students raised their hands) implying some students’ inability to recall or describe the process involved in the formation of water molecule. After a pause, one student correctly recalled the information: “Two molecules of hydrogen combine with one molecule of oxygen to form water.” The teacher wrote the statement on the chalkboard and invited students to represent it in the form of chemical equation (using symbols). This time, relatively a less proportion of students, showed their interest to come forward and write the chemical equation. One student came forward and, with trial and error, she wrote the equation: H₂ + O₂ = H₂O. The teacher praised the student’s effort and at the same time challenged her that what she had produced was not 100% correct. The teacher invited other students to recognize what was lacking in the equation and then to add the missing element so that a “balanced equation” was obtained. The teacher asked the class to complete the equation on their notebooks. It appeared that only a few students seemed to have the ability to correctly answer the question (successfully attempted the question: 2H₂ + O₂ = 2H₂O).

Finally, teacher asked for justification (reasoning) as why it required them to add 2 with H₂ (reactant) on the left-hand side and 2 with H₂O (product) on the right-hand side of the chemical equation. Hardly 2 students out of 29 present in the class offered reason as why modification was required in the equation and how it was made.

**Discussion**

To reflect through the findings regarding the difficulties underlying in-depth student learning, I briefly examined the nature and the causes of the difficulties students are faced with in coping with the concepts cited above and teacher’s action to remedy the situation.

In chemistry, the concept of “atomic model” and allied subconcepts form the very foundation on which learning of the entire discipline depends. It may not be an exaggeration to describe knowledge of atomic model combined with some of its primary allied concepts as a backbone of the understanding of the knowledge base of the whole discipline. Poor understanding of these fundamental concepts, therefore, has tremendous implications for the conceptual learning of numerous concepts in the temporal chemistry curriculum.

The teachers’ reflection combined with observation of a couple of chemistry lessons revealed atomic model to be a problematic area where students lacked depth and breadth of understanding. They often confused the definition of the “atomic number” with the definition of “mass number” and position of the atomic particles and their characteristics with each other (e.g., associating positivity with electron and negativity with proton, locating proton in the orbit, and associating electron with nucleus). In normal learning setting (like in schools in Gilgit-Baltistan), students do not have the facility to do experimentation or physically observe phenomena to verify the information and ideas presented to them about the concept through textbook or teacher’s lecture. Usually analogies, models, diagrams, and imageries are used in the textbooks and by the teachers to help facilitate the learning about atomic model and its allied concepts. These strategies are important and effective on their own right; however, they may not provide sufficient conditions to help develop conceptual understanding of the topic. This necessitates an ongoing quest for instructional strategies and resources to effectively deal with the challenge of teaching atomic model and its allied concepts in the context of chemistry classroom. The federal government has provided computers in many high schools under the national computer literacy program. Teachers in these schools can use computer simulation to help students better comprehend basic abstract scientific ideas related to atomic structure.

In the above Example II, the difficulty lied in students’ poor understanding of the primary knowledge in the background of the formation of ionic compounds or bonding relationship between and among elements. They have already been introduced to the “law of definite proportion” in chemistry, but they were unable to apply it to the situation at hand: formation of the ionic compound CaCl₂. Students thought that in the CaCl₂, Ca²⁺ combined with 2Cl⁻; the misconception lied in the fact that Cl⁻ + Cl⁻ = 2Cl⁻ instead of conceiving it as Cl⁻ + Cl⁻ = Cl⁻² (Cl₂: molecule of chlorine with two negative charges). Students were confused that why Ca²⁺ + (Cl⁻ + Cl⁻) is written as CaCl₂ why not 2CaCl. This misconception must have different origins. The teacher believes that, may be thinking in a linear way, the students applied the rule of algebra, in which, x⁻¹ + x⁻¹ can be written as 2x⁻¹, so why Cl⁻¹ + Cl⁻¹ should not be written as 2Cl⁻¹.

The teacher’s remedial efforts appeared to be rigorous enough to help students overcome the conceptual confusion they harbored and bridge the knowledge gap. The teacher verbally as well as diagrammatically explained the law of definite proportion and showed on the chalkboard how it applied to the example at hand. He explained that Ca carried two plus charges (Ca²⁺), whereas Cl carried one minus charge. So to form ionic bond between Ca and Cl, two atoms of Cl were required. The total charge on Cl molecule taking part in the reaction would be −2, and the number of chlorine atoms in the chemical formula of the ionic compound would be represented by Cl⁻ instead of 2Cl, which has an entirely different meaning in the context of balancing chemical equations.

In the example at hand (2H₂ + O₂ = 2H₂O), students were required to balance the chemical equation and explained the
process (what was done and why?). Presumably, the students who were reluctant to raise their hand might have had difficulty in recalling the information. For some students, it was difficult to symbolically represent \((\text{H}_2 + \text{O}_2 = \text{H}_2\text{O})\) the statement about formation of the water molecule. Other students were able to answer the question; nevertheless, they legged behind in demonstrating yet another level of knowledge of the topic, balancing the equation \((2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O})\). Fewer students even demonstrated the knowledge about balancing chemical equation (probably out of memory, not out of understanding), but they failed to explain why they added 2 with H on the left-hand side and 2 with the product on the right-hand side of the equation. In other words, they were unable to physically explain the phenomenon.

The conceptual hurdles students are faced with in learning subject-matter knowledge, such as balancing chemical equation, do not exist in isolation; rather, they are interlinked in complex ways. This implies that “understanding” concept such as chemical equation is a multilayered and dynamic phenomenon. As seen in the above example, student’s recalling or constructing equation of the formation of water molecule does not necessarily amount to confirmation of their learning the concept with understanding. A clear trend is reflected in this example, in which, as the concept grows complex, students’ responses decrease sharply. This exemplifies the multilayered and dynamic natures of the notion of in-depth learning of scientific concepts.

These various facts explain the complexity of the situation teachers are faced with in dealing with the situations such as assessing students’ prior knowledge of the subject matter, catering to or dealing with individuals’ level of understanding or learning needs and thereby achieving uniformity in students’ level of understanding of the topic.

The mediocre culture that prevails in science classroom in public and private schools in Gilgit-Baltistan may be attributed to the challenges faced at multiple levels ranging from lack of educational resources (laboratory equipment and library resources) to poorly qualified or untrained teachers to teach science subjects. Students studying science course in secondary schools in Gilgit-Baltistan are ill prepared to pursue higher studies in science. The study has provided insightful information into some of the common factors that contribute toward the invariable decline in the quality of science education imparted in schools in Gilgit-Baltistan. Various social factors, contextual or cultural factors, and academic factors combine to affect students’ attitude, their ability to engage in science learning, and their achievement. Science curriculum cannot be developed and implemented in isolation. Development and implementation of curriculum need to take into account social structures and economic conditions of the local context into account.

Conclusions and Implications
The main learning objectives emphasized in the chemistry curriculum not only stress the need for students to learn and master primary concepts of chemistry but also undergo intellectual development as scientifically literate citizen. These objectives can only be achieved if students gain conceptual understanding in science knowledge. Not a single factor contributes to conceptual learning but it occurs within a milieu which in turn is a result of interplay of multiple factors ranging from curriculum to teachers’ ability to structural and human resources. Efforts toward promoting conceptual learning in science classroom or development of students’ cognitive skills need to be informed by the knowledge and understanding contributed by different genre of research such as a cognitive psychology, social psychology, and attitudinal and intervention-based research. It is now well established that what an individual learns is as a result of the learner’s actively relating what is already known to what is being taught or experienced.

The anecdotal evidence from the research participants’ teaching context presented and discussed above exemplify the challenges and the common conceptual difficulties students usually face in learning subject matter in chemistry classroom in high schools in Gilgit-Baltistan. It appears that in the context of each situation presented above, the crux of the matter lied in the poor background knowledge students brought to the learning situation. It is evident from the above examples that students of Grades 9 and 10 (age level 15-16) failed to demonstrate very basic understanding of chemistry concepts. Fundamentally, the challenges seem to arise from students’ poor subject knowledge background, which apparently is the consequence of the poor teaching, inadequate academic support and guidance, and insufficient individual attention they received from their environment (subject teacher, school, parents, and peers). Lacking essential knowledge of the primary chemistry concepts, which needed to be learnt and mastered at lower secondary levels, students seemed confused despite teacher’s good efforts to communicate the concept using a variety of simple examples and explanations. This suggests that until and unless students bring a good understanding of the very basic concepts to the learning situation, they may not be able to cope with the advanced level knowledge. This underscores the critical importance of students’ learning basic science concepts in the early stages with understanding.

The insights offered and the concerns raised in the article seem to have important implications for understanding classroom realities (imperatives and impediments of in-depth student learning) in Pakistan in general and in Gilgit-Baltistan in particular. Specifically, the implications of the results of this study can be seen and explained in the context of schools, teachers, and other educational stakeholders.

Students’ learning of subject matter with deeper understanding may not take place in the classroom in an isolated fashion. In-depth leaning is closely connected with various conditions inside and outside the classroom. This calls for synchronization and integration of efforts on the part of school. Schools need to create situations where teachers are encouraged to reflect on their own practices and engage in
efforts to improve their general as well as subject-based pedagogical skills. The high demands of conceptual learning require chemistry teachers to let go of transmission-oriented practices; they need to carefully prepare lesson plans, student worksheets, assignments, and assessment tasks to be able to think about and convey the subject matter in different ways.

Recognition of the teacher’s vital facilitative role in in-depth student learning necessitates equipment of teacher with professional competencies (knowledge, skills, and disposition). Unfortunately, most traditional pre- and in-service teacher training program in Pakistani context do not provide necessary conditions to help inculcate and nurture these critical professional qualities in teachers. This entails a new vision of education and professional growth for teacher compatible with a vision of pedagogy. So the efforts in the context of reforming science teacher education in Gilgit-Baltistan as well as in the country need to be geared toward “pedagogy of understanding” (Perkins, 1993) to help science teachers acquire the requisite knowledge and skills. The “pedagogy of understanding” may be explained in terms of teachers knowing about creative ways of promoting in-depth student learning. Teachers need to make instructional selections from among an array of choices comprising teaching methods and models, teaching acts and instructional strategies such as practical work, interactions through group work or pair work, presentations, whole class discussion, application of knowledge, use of creative motivational techniques, questioning, and applying problem solving or inquiry-oriented instructional strategies. It is only thorough these action, the goals of National Curriculum can be realized.

All of the above would require schools to recognize the vital importance of long-term planning, preparation, and well-structured and well-thought strategies instead of depending on incidental measures to deal with the difficulties arising from teachers’ inability to promote in-depth student learning in such important curriculum subjects as chemistry. Most of the high schools in Gilgit-Baltistan enroll students from Nursery to Grade 10. Science course is an integral part of school curriculum. The schools need to pay heed to the fact that the way science course is taught in schools is not helpful at all to nurture scientific thinking and develop a strong base for advance studies in science. Schools need to take all possible measures to create an environment in primary science classroom where teachers and students engage in activities that help them enhance their cognitive skills and develop mastery of primary science concepts. Students transiting to upper grades with adequate knowledge base and cognitive skills can easily cope with the demands of the middle or secondary science curriculum. Moreover, schools, teachers, district education department, and the authorities (examinations boards) need to work together to help evolve an examination system that gives importance to learning and cognitive development instead of the traditional emphasis on syllabus coverage, which has become almost a necessary evil. Teachers and schools need a certain degree of freedom in making decisions with regard to syllabus coverage and preparing students for internal and external test/exams.

Finally, lessons learnt in this study have important implications for all key stakeholders, including teachers, administrators, students, parents, practitioners, and policy makers. Improvement in science education in schools may not be achieved in schools, in general, and in government schools, in particular, without concerted and consistent efforts on the part of the above key stakeholders.

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**Bio**

Takbir Ali holds a PhD degree in education. He is working as a senior instructor at the Aga Khan University-Institute for Educational Development, Pakistan. He has research interests in teachers’ change experiences, teachers and curriculum implementation, school improvement, and teaching and learning science in schools.