Texila International Journal of Academic Research
Volume 5, Issue 2, Oct 2018

Investigating the Areas of Student Difficulty in Chemistry Curriculum: A Case Study in Qatar

Article by Caleb moyo
Education, Texila American university, Qatar
E-mail: cmoyo@texilaconnect.com, moyocaleb@yahoo.com

Abstract

The exploratory study focused on the identification of difficult topics in Chemistry in the International General Certificate of Secondary Education (IGCSE) curriculum. A structured questionnaire was used to obtain data from thirty students by simple random sampling technique. Interviews and focus group discussions were carried out to seek clarifications on some of the responses to the questionnaire questions and to elicit detailed explanations of the causes of the perceived difficulties. A multiple-choice test was also administered for the purpose of triangulation. Frequencies and means were used to answer the research question. The findings indicate that the causes of poor performance could be categorised into five groups i.e.: nature of concepts, prior knowledge, access to the language of instruction, teaching processes and mathematical efficacy. The study recommends a more structured form of curriculum mapping of all topics and sequencing of topics over the two-year period of study of IGCSE Chemistry and suggests further research on misconceptions and their origins in the subject matter.

Keywords*: chemistry, difficulty, concepts, abstract, igcse, sub-micro.*

Introduction

Research on students' conceptual knowledge of chemistry has been largely based on the constructivist view of knowledge (Bodner, 1986; Osborne and Witrock, 1983). In this view, the students build cognitive structures based on their own understanding (Nahkleh,1992) and hence since the students construct their own views of concepts, their construction of chemical concepts sometimes differs from that held by the generality of the scientific community (Treagust,1988). Research to reveal these alternative conceptual frameworks (Driver,1981) has been carried out by many researchers like Bradley et al, 1990; Renstrom, 1990; Ogunniyi, 1991; Banerjee,1991; Ogude and Bradely, 1994; Treagust and Niaz,1995; Themas and Shuenz,1998. The results of research have been used to improve the teaching and learning of chemistry for example, in modifying the curriculum (Blanco and Prieto, 1997), to formulate examination questions (Treagust, 1988) and to design exemplary teaching materials (Bradely, et al, 1990). Conceptual understanding difficulties, however, cannot be addressed if the strategies do not take into account the fact that daily social experiences that students have, contribute to inaccurate conceptions about diverse scientific phenomena (Ogunniyi, 2000). Furthermore, Driver and Erickson (1983) concluded that learners construct conceptual frame works for interpreting natural phenomena on the basis of previous experiences. Acknowledging the influence of social experiences (Ogunniyi, 2000) and previous experiences (Driver and Erikson, 1983), on the process of learning, means that research on conceptual understanding has to be carried out within the context of the learner for the results to be more meaningful.

Research on conceptual understanding has been criticised by various other researchers. Cohen, 1996 and Gil-Perez, 1996 opined that this type of research tends to result in conceptual reductionism (Gil-Perez, 1996). Such an approach limits science education to the learning of science concepts only, yet there is a plethora of other crucial factors like epistemology, conceptions of how knowledge is constructed and views about the nature of science, (Nos), (Gil –Perez, 1996), that also influence the way Science is learned. Research on conceptual understanding has been criticised because it isolates the students from other domains of

DOI: 10.21522/TIJAR.2014.05.02.Art003
ISSN: 2520-3088

knowledge, (Fensham, 1983) and does not view the fact that the classroom is a complex socio-cultural environment (Cobern, 1996). Consequently, research on conceptions just focusses on conceptual learning without considering the learning environment. Furthermore, studies examining cultural influences on learning Science have shown that culture controls both the teacher and the learners' understanding of Science (Krugley-Smolska, 1995; Lynch and Jones, 1995 and Maskill, et al, 1997). The results obtained by Lynch and Jones (1995) show that Science Education needs to be viewed in the context of the worldview in which both language and culture affect concept learning and understanding. Over the years Qatar has increasingly used a foreign Science curriculum, which uses English language as a medium of interaction. Such curriculum could be described as culturally insensitive (Ogunniyi, 1997) and hence may fail to address the learning difficulties of Qatari and other foreign students effectively.

Apart from misconceptions, there are other reasons that affect students' performance in Chemistry. As a result, strategies based on the research findings of conceptual research on their own will have little effect on the improvement of subject performance, (Zoller, 1990). The chemistry content has ….' many abstract, non- intuitive concepts which are not directly related' (Zoller, 1990). Nahkleh (1992) also concluded that the problems with freshman chemistry were caused by lack of proper introduction to students, of fundamental chemical concepts like matter resulting in students failing to grasp advanced concepts. The above studies demonstrate clearly, the need for a comprehensive approach to teaching and learning chemistry. Focusing on individual aspects without taking into account the whole puzzle will continue to result in poor performances in chemistry. Often, when teachers are introduced to some of the strategies like active learning approaches and context led teaching, they agree that the strategies are good and would improve understanding but in the same manner, they would vibrantly discuss other subject issues that they think are more pertinent. These factors must be taken into account even though the primary task would be to introduce active learning approaches and they need to be investigated in context.

Purpose of the study

The main purpose of this study was to identify the areas or topics in the secondary school chemistry curriculum which students and teachers consider difficult. Specifically, this study aimed at identifying the content areas in the chemistry curriculum at the IGCSE level, which the students find difficult. The data obtained will help improve student understanding of concepts, help teacher planning and lesson preparation and make the teaching and learning of the students more meaningful and productive.

The following research question was addressed:

What are the causes of poor performance in chemistry as perceived by igcse chemistry students and teachers?

Methodology

Thirty (30) students from one school were the subjects of the study due to the ease of accessibility to the researcher. The study made use of information gathered through a structured questionnaire given to year 11 students, (in their final year of the two year course).

Interview questions were used to collect data from 4 teachers in the same school and from year 11 students through a focus group discussion. Interviews and focus group discussions were audio taped and later transcribed verbatim.

An objective multiple-choice test was also administered to determine those sections in which the students would score low marks. The test was piloted to verify the readability of the questions. Interviews were used to clarify issues identified in the questionnaire and the multiple-choice test.

The student questionnaire was designed by the researcher and piloted to a sample similar to the one involved in the main study. The questionnaire consisted of a series of syllabus objectives per topic in which students indicated their options on a five-point likert scale with responses ranging from 1= Not studied, 2= Very Easy, 3= Easy, 4= Difficult and 5= Very

Difficult. A reliability test was carried out on the instrument and Cronbach's alpha was **.**935 which is considered adequate. Frequencies and means were calculated for each response.

The chemistry teacher's views were based on their empirical experiences of how students viewed chemistry as a subject, the topics/ concepts their students found difficult to learn and master and consequently those that they found difficult to teach. The teachers were asked to give reasons for the difficulties from their perspective. The students provided information about the difficult areas and reasons as to why the topics were seen as difficult. Students gave insights into how they perceived how they were taught in the subject.

Findings and discussion

Students and teachers were asked to describe topics and specific concepts that they found difficult to understand. The percentages of students and teachers indicating the topics are given in table 1. From the table, it can be observed that the teachers rank difficult topics as the mole concept calculations (64%). This was also mentioned by the students; electrolysis and half equations (51%); chemical and ionic equations (39%) which were noted by the teachers as well; drawing of displayed formulae (68%); experimental work (59%) which was not mentioned by the teachers; chemical equilibrium shift (59%) and oxidation – reduction (redox), 63%.

Furthermore, students and teachers were asked to explain why these topics were perceived as difficult. While questionnaires and interviews were used to collect the data, this data is discussed in sections that emerged from the survey which are: nature of subject, prior experiences, mathematical efficacy, teaching and learning processes and the role of the language of instruction.

Table 1. Perceived difficult topics in IGCSE Chemistry by students and teachers

Topic	Teachers (N=4)	Year 11 students (N=30) / %	Mean test score (N=30) / %
1.The mole -too many formulas to remember -difficult to use ratios	3	51	42
2. Redox -writing half equations -predicting the product at electrodes	3	39	33.8
3. chemical equilibrium -predicting the shift in position of equilibrium	3		39.8
4. Chemical formulae and equation - writing chemical formulae and equations -writing ionic equations	4	51	43
5.Electrolysis - half equations -net equations -movement of ions during electrolysis -predicting products at electrodes	4	58	42.8

DOI: 10.21522/TIJAR.2014.05.02.Art003
ISSN: 2520-3088

6.Polymerisation -types -drawing displayed formulae of different polymers and monomers	3	46	59.1
7. Energetics -calculation of heat change per mole -relating heat change to energy profile diagram	3	41	47.3

Prior knowledge

According to Treagust et al, (2000), there is overwhelming empirical evidence in the literature that what students already know is the key factor in learning. Usually students' pre-instructional conceptions provide frameworks that are not in accordance with the science conceptions to be learned.

All the four teachers agreed that students have difficulty mainly because of their weak background at key stage 3 level. The teachers indicated that students came into the key stage 4 phase with an inadequate conceptual understanding of basic Science knowledge. Of the total students who participated in the study, 13 of them agreed that they had not been screened at the beginning of their course (end of year 9) and 18% of them had their final year 9 grade below 60% which is a level 3 out of 7. A few students came from other schools with different curriculum systems. This could explain why the students found the subject difficult.

Students lamented that sometimes their teachers did not focus much on preparing them for key stage 4 Science "because they did not teach key stage 4 classes they did not know the important things for key stage 4.…" So, while the importance of key stage 3 science in laying the foundation cannot be overemphasised, it is worthwhile to scrutinise the nature of Science.

Nature of the subject

Table 1.1. Write ionic half-equations representing the reactions at the electrodes during electrolysis

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Easy	8	26.7	26.7	26.7
	very easy	10	33.3	33.3	60.0
	difficult	10	33.3	33.3	93.3
	very difficult	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

All teachers concurred that students would still select Chemistry due to it being a conditional subject for their career choices. Students indicated that Chemistry was demanding in terms of concentration, time, its abstract nature and that is why they did not find the subject easy.

In figure 1.1 the abstract nature of the subject was further confirmed by the fact that students expressed anxiety with writing of equations (ionic) (66.6%), prediction of products at the electrodes and representing displayed formulae of monomers and polymers. In electrolysis, students indicated that they could not understand how ions moved as it … 'was hard to visualise how ions moved from one electrode to another".

More so, all the 4 four teachers agreed that the subject used a lot of calculations and often students did not have a formula sheet with the question paper and this discouraged the students in studying the subject. Furthermore, students had also indicated that mole calculations were very difficult to understand, hence in the end, they tried to memorise the formulas and procedures that would help them get the answers correct without necessarily understanding what was going on. Students added that they sometimes needed a lot more time to practice questions on calculations, however these were almost present in every chapter and that puts a lot of pressure on remembering formulas. Some students (8%) also indicated that the teaching of moles could have been done using a practical approach so that they could follow what was going on instead of simple manipulation of numbers in class. It is important to mention that while calculations are an integral part of the subject content, they cannot exist in isolation to the theoretical aspects of the subject and the related practical work.

Teaching process

The results of the focus group discussion were based on students' answers to the question, why they found the concepts difficult. The responses were grouped under teaching practice and with strongly emerging factors of curriculum mapping and teaching processes. Students concurred that being in an international school teacher came and left the school inadvertently, not necessarily at the end of their contracts.

The consequences of frequent teacher turnover to a school can be catastrophic. It can adversely influence curricular and program continuity, result in a negative shift or sustainability of schoolwide initiatives, and cause a serious loss of the dynamic stability and continuity of the important relationships that exist among teachers, students, and other school community members and present obvious negative effects on schools operating budgets (Mancuso, 2010; Wu, 2012) in Tkachyk, L, 2017 pp 14. This means a lack of continuity in syllabus coverage such that a replacement teacher usually has a different if not divergent approach to the previous one. Some went on to say that in such instances there was no order in the teaching of topics and sometimes this made it difficult to connect the concepts in a logical manner.

"The curriculum is a sophisticated blend of educational strategies, course content, learning outcomes, educational experiences, assessment, the educational environment and the individual students' learning style, personal timetable and programme of work", (Harden, R, M,2009). Curriculum mapping assists staff and students by displaying the key elements of the curriculum, and the relationships between them. Students can identify what, when, where and how they can learn. Staff can be clear about their role in the big picture. The scope and sequence of student learning is made explicit, links with assessment are clarified and curriculum planning becomes more effective and efficient, which means that any new member of the department will simply follow what is laid down.

Lack of experimental practical work

Students lamented their lack of practical experiences in some topics and teachers also agreed that experimental work was usually a challenge given the numbers of students in each class, the size of some rooms and the lack of trust of the students to independently follow a set of instructions from the teacher within the given time. Classes have a maximum of 25 students especially in key stage 3, however the Science rooms were designed to cater for 18 students comfortably. The performance of experiments would be a slightly challenging feat. It is however important to carry out experiments with students since they have a paper 2 examination with a bias towards experiments. Students also indicated that some teachers simply read what was in the textbooks without much explanation.

Trna, J, (2014), opines that the experiment is a strong educational tool, which plays a crucial role in science education (p.9). He goes on to say that this is due to the decisive role of experiments in science research and the cognitive importance of experiments in science education. That is why science teachers' professional competence in using science experiments for teaching/learning science is a very important part of their education (Trna, 2000). Teachers' skills in experimentation play a crucial role overall and are a very important part of their pedagogical content knowledge (PCK) and continuous professional development (CPD). Experience in the use of science experiments is an integral part of the individual PCK of every science teacher (Royer, Cisero, & Carlo, 1993) as cited in Trna, 2014. A crucial point of science teachers' professional competence in using experiments should be their motivation for experimentation.

DOI: 10.21522/TIJAR.2014.05.02.Art003
ISSN: 2520-3088

Teachers felt that they could demonstrate some experiments in order to overcome logistical challenges, however students expressed interest in doing the experiments hands-on. It is clear that students believe that if they could perform experiments during lessons, this would enhance their retention of concepts.

Mathematical efficacy

Teachers and students concurred that mathematics was important in Chemistry and more so teachers felt that some students tended to compartmentalise the subjects such that ratios in mathematics were perceived differently to ratios of moles in Chemistry.

According to Furner and Kumar, 2007, more and more educators are coming to realize that one of the fundamental problems in schools today is the "separate subject" or "layer cake" approach to knowledge and skills. Often students cannot solve problems because they do not understand the context in which the problems are embedded (Frykholm & Glasson, 2005), however they go on to suggest that, "if done properly, integration of math and science should bring together overlapping concepts and principles in a meaningful way and enrich the learning context." This suggests that there is a need to integrate math and science for the acceleration of transfer of learning between both subjects. This also means that teachers, upon realising that students have not transferred their learning math's skills to Chemistry, must emphasise the fact that mathematics is a tool used to quantify variables through concrete student activities in science classes, hence the need to link to practical work.

The role of language

The research was done in an international school, with students from a diversity of cultures and backgrounds. One striking feature is that most of these students (>80%) speak English as a second or third language. Arabic is the mother tongue of most students and teachers also confirmed that the language issues contributed to the difficulty of the subject content. Teachers explained that students could not sometimes, discern the key words in the questions, hence they gave somewhat irrelevant answers. One teacher stated that…" students' answers to descriptive questions are often poorly answered". Students explained that although they understood the content, it was always difficult to understand what the question required them to do.

Mammino, L, (1998) stated that, "Science students experience difficulties with the language of science all over the world", and moreover, "students using a second/foreign language as a medium of instruction experience the additional difficulties related to such use". The overall combination of the language-related problems is probably the major cause of the difficulty's students encounter in their approach to scientific subjects. This suggests that teachers must unpack keywords, during lessons, work on literacy by way of command words used in the subject, identification of underlying key words in questions and other retention enhancing methods.

It is also vital for teachers to be cognisant of the fact that Chemistry is commonly portrayed at three different levels of representation – macroscopic, sub microscopic and symbolic – that combine to enrich the explanations of chemical concepts (language), Treagust et al, (2010). While Wu, H et al, (2003) opine that chemists represent sensory experiences by atoms and molecules, and translate them into symbols and formula. However, understanding microscopic and symbolic representations is especially difficult for students. Students' difficulties have been attributed to several factors, such as the aperceptual nature of atoms and molecules (Ben-Zvi, Eylon, & Silberstein, 1986), students' incomplete or inappropriate mental models (Kozma et al., 1996; Williamson & Abraham, 1995), and discrepancies between school science and students' real-life experience (Osborne & Freyberg, 1985) as cited in Wu, 2003.

Teachers must exploit as many opportunities as possible to link the symbolic, to the micro and the macroscopic language, hence the importance of exposing students to practical work including predictions of outcomes and the reasoning or explanations of such using equations. Word walls can also assist student memory as they are constantly in contact with the words every time they come into the room. Students can only understand when they can transit through the different forms of representation of the chemistry language with relative ease and comfort.

Conclusion

The study explored the causes of poor performance in chemistry at the IGCSE level. It is concluded that according to the teachers, the subject has many abstract concepts and the situation is even worse when the students are second language learners. Chemistry also uses the micro and symbolic forms of language which pose a significant hurdle for the students to explain phenomena at the macroscopic level (the triplet). Teaching must then be geared towards helping the students to make connections between these three forms.

Students must interiorise, process ideas and then verbalise their thoughts which is no mean feat for second language English speakers. Language poses a huge threat to understanding of concepts. Teachers and curriculum developers need to look at ways of making content more accessible to non-native English speakers.

Mathematical efficacy is a necessary requirement in the subject. There is a need to look at inter-curricular links especially with Mathematics so that learners can easily transfer and apply process skills to science subjects. Subject planning must also take into account students' pre-requisite mathematical knowledge in the different topics.

It must also be mentioned that poor planning in terms of curriculum mapping, learning and teaching processes has compounded the issue of subject difficulty. Long term plans must give detailed information on what is to be studied and exemplar practical activities for each section. Practical activities should be suggested for concept development and consolidative purposes. Teacher mobility in international schools is a global phenomenon which should not be a cause for concern if long and medium term teaching plans are properly executed and reviewed constantly as per the requirements of specifications. It is also important to target further research on misconceptions and their origins in the topics of appreciable difficulty as determined in this study, such as the mole concept, electrolysis and others in the context of language.

References

[1]. Banerjee, A. C. (1991). 'Misconceptions of students and teachers in chemical equilibrium'. International Journal of Science education, 13, 4: pp 487 - 494.

[2]. Bodner, G. M. (1986). 'Constructivism: A theory of knowledge', Journal of Chemical Education. 63, 10, pp 873 – 878.

[3]. Gill-Perez, D.: 1996, 'New trends in science education', International Journal of Science Education, 18, 8, pp 889 – 901.

[4]. BouJaoude, S., & Barakat, H. (2000). Secondary School Students' Difficulties with Stoichiometry. School Science Review, 81 (296), 91 – 98.

[5]. Coll, R. K., & Treagust, D.F. (2009). Learners' use of Analogy and Alternative Conceptions for Chemical Bonding, Australian Science Teachers Journal, 48(1), 24 – 32.

[6]. Cohen, L., Manion, L., & Morrison, R. (2003). Research Methods in Education. (5th ed.). Routtlege Falmer, London & New York.

[7]. BouJaoude, S., & Barakat, H. (2003). Students' Problem-Solving Strategies in Stoichiometry and their Relationships to Conceptual Understanding and Learning Approaches, Electronic Journal of Science Education, 7(3), online journal, http://unr.edu/homepage/jcannon/ejse/ejse.html

[8]. Christie, A. (2005). Constructivism and its implications for educators' http://alicechristie.con/edtech/learning/constructivism/index, Gtm.

[9]. Furio, C., Azcona, R., & Guisasola, J. (2002). The learning and teaching of the concepts "amount of substance" and 'mole': a review of the literature. Chemistry Education Research and Practice, 3, 277 – 292.

[10]. Mammino, L. (2010). The essential role of language mastering in science and technology education. International Journal of Education and Information Technologies, 3(4), 139-148.

[11]. Nakhleh, M.B. (1992).'Why some students do not learn Chemistry', Journal of Chemical Education, 69, 3,191 – 196.

DOI: 10.21522/TIJAR.2014.05.02.Art003
ISSN: 2520-3088

[12]. Ogunniyi, M.: Pupils' ideas about selected Physical Science concepts'. Proceedings of the 8th annual SAARMSTE conference, ed. Mahlomaholo, S.
[13]. Treagust et al, (2003), 'The role of sub microscopic and symbolic representations in chemical explanations', 25, 11, pp.1353-1368, Routledge.
[14]. Doi: 10.1080/0950069032000070306.
[15]. Treagust, D.F.: (1998), 'Development and use of diagnostic tests to evaluate students' misconceptions in science', International Journal of Science Education 10, 2, 159 – 169.
[16]. Tkachyk L, M. (2017). Perceptions of International Teacher Turnover in East Asia Regional Council of Schools.
http://scholarworks.waldenu.edu/dissertations
[17]. Zoller, U.: (1990), 'Students misunderstandings and misconceptions in college freshman chemistry', (General and Organic), Journal of Research in Science Teaching, 27, 10, 1053 – 1065.