ASSESSMENT OF UNDERGRADUATE CHEMISTRY STUDENTS' DIFFICULTIES IN ORGANIC CHEMISTRY

Ayalew Temesgen Eticha
Institute for Science and Technology Education
Email: Ayalew_temesgen@yahoo.com

CE Ochonogor
Institute for Science and Technology Education
Email: Ochonec@unisa.ac.za

Abstract: The purpose of this research was to investigate specific areas of difficulty for undergraduate University students in Organic Chemistry and to identify the sources of difficulty for Chemistry students in order to scientifically determine ways of improvement. The study was conducted in three years with 177 first year Chemistry students and 4 Organic Chemistry lecturers who have minimum five years teaching experience. Document analysis of examination scripts of 177 Chemistry students based on 54 Organic Chemistry questions, interviews on sampled Chemistry students, and questionnaires administered on all the 177 Chemistry students as well as the 4 Organic Chemistry lecturers were analysed. The Chemistry teachers' questionnaire investigated the teachers' perceptions about teaching Organic Chemistry in terms of any difficult topics, to identify the sources of difficulty, and to identify possible ways of improvement. The document analysis was conducted to assess students' achievement and to evaluate students' abilities and difficulties in solving Organic Chemistry problems. The main areas of difficulty identified by teachers and students in this study include **functional groups, stereochemistry**, and **organic reactions and mechanisms** among other selected topics. Several reasons and factors were adduced for the observed difficult aspects of Organic Chemistry, among which are: inappropriate Chemistry teachers` teaching methods, nature of the subject itself, students' attitude and learning experience and learning style. Several ways of improvement have been discussed in the paper.
Key words: *Achievement, Attitude, functional groups, organic reactions, reaction mechanisms, stereochemistry, two-dimensional form, three-dimension, visualization.*

INTRODUCTION

Chemistry is an essential basis for everyday lives, and has many unforeseen potential benefits for our future. An understanding of Chemistry allows us the opportunity to explain the world around us; and to make informed decisions concerning our actions as individuals. Generally, understanding of Chemistry is necessary for working in almost all the other sciences such as material sciences, engineering, environmental sciences, and medicine. Students opting for any of these career fields need good knowledge in Chemistry and about current trends in Chemistry (Ingo Eilks and Avi Hofstein; 2013).

Many scholars have identified Organic Chemistry as a hard course and many college students who wish to pursue a career in Chemistry and medicine must have a solid understanding of Organic Chemistry and perhaps more importantly to the students, a good grade in Organic Chemistry. However, the difficulty of the Organic Chemistry materials prevents many students from continuing with this career path. One of the major difficulties for students in Organic Chemistry is that of understanding the three-dimensional nature of molecules. Students usually have no good background in three-dimensional visualization and have great difficulty in navigating between the two dimensional drawings used in text books and classroom chalkboards drawings to represent molecules and their three-dimensional structures (Girija S S and Deepa S. M., 2004; Gilbert 2005; Uttal and Doherty 2008; Michael Corrin, *et al.,* 2013). Without this understanding, students memorize a large vocabulary of

molecules and rules to fake an understanding of the three-dimensional structures in order to survive in the course.
Organic Chemistry is commonly found problematic and Chemistry students eventually develop a wide range of alternative conceptions (Stieff, 2007). Apparently, stereochemistry requires the use of Visio-spatial strategies because scientific problems often require explicit consideration of spatial relationships (Gilbert, 2005), and chemists might mentally rotate visualized molecules when designing new pharmaceuticals (Habraken, 1996). Correspondingly, different studies on stereochemistry (three-dimensional aspects of molecules and their relationships to other molecules) showed that, it is frequently a source of confusion for undergraduate Chemistry students (Gilbert 2005; Michael Corrin, *et al.*, 2013; Bowen and Bodner, 1991; and Izzet Kurbanoglu, *et al.*, 2006).

The importance of Organic Chemistry in our everyday life cannot be overemphasied since it deals with most aspects of the Chemistry of carbon compounds, which are the building blocks for all living organisms. However, different research reports showed that, Organic Chemistry is difficult subject for students who pursue their education in this career (Anne O' Dwyer and Peter Childs, 2010*;* Johnstone 1991; Sirhan G., 2007; Bhattacharyya and Bodner 2005; Ferguson and Bodner 2008; and Childs and Sheehan, 2009). But their reason, of difficulty may different from one person to the other. According Ellis, (1994) the difficulty of Organic Chemistry for students is because of: there are no algorithms for solving problems, it requires three-dimensional thinking and the new vocabulary to be learned is very intensive; Johnstone (1991), indicated that the nature of Chemistry concepts and the way the concepts are represented (macroscopic, microscopic, or representational); teaching method by which students learn are potentially in conflict with the nature of science, or the methods by which teachers have traditionally taught (Johnstone, 1991; McCormick and Li, 2006; Simsek, 2009); teachers` lack of an accurate awareness of their pupils' prior knowledge, misconceptions and level of cognitive development, and students' attitudes and approach to learning, (Anne O' Dwyer and Peter Childs, 2010).

Numerous research reports expressed that the difficulties in Chemistry arise from the abstract, complex and dynamic nature of the concepts covered, bulky course content, teacher-centred teaching, erroneously constructed students` knowledge due to lack of clear vision, and lack of students` and teachers` motivation. Anne O'dwyer, (2012) and Millar (1991) categorized the factors which contribute to difficulty of Organic Chemistry as the extrinsic difficulties (factors referring to issues that are beyond the control of learners); and intrinsic difficulties (factors referring to difficulties faced by individual learns and supposed to be within their control).

Though extensive reseaches have also been carried out in investigating the difficulties that learners have with Organic Chemistry in other parts of the world, there is no such research work that has been done in Ethiopian higher education in Organic Chemistry courses to the knowledge of the authors on the situation in the teaching-learning environment. It has been observed that many students work hard with course materials in Organic Chemistry in the Chemistry department at Haramaya University. However, their examination results show that a great number of them often seem not to be achieving well as they scored less than acceptable mean of 50% in functional group, stereochemistry and organic reaction and mechanism topics. Though they seem to be working hard, they do not acquire the necessary knowledge and cannot express their answers clearly and logically too. In order to facilitate students learning, many lecturers put their efforts in making them to be actively engaged in the construction of their own knowledge when they give lectures on Organic Chemistry.

However, not much significant change is observed in this regard. Chemistry teachers blamed students because they scored low grades in the subject and on the other hand, Chemistry students blamed their teachers. A number of researches reported students' difficulty in Organic Chemistry in different countries and yet no studies of this nature have tried to identify the specific areas of difficulty in Organic Chemistry for University students and the source of such difficulties in Organic Chemistry in Ethiopian. Therefore, this study investigated the specific areas of difficulty in Organic Chemistry topics for University students and the source of such difficulties for University students with recommendations on how to improve the situation.

Research Questions

The following two research questions have been addressed in this report:

- What are specific areas of Organic Chemistry topics difficult for University students?
- What are the causes for these difficulties in Organic Chemistry?

Objectives of the research

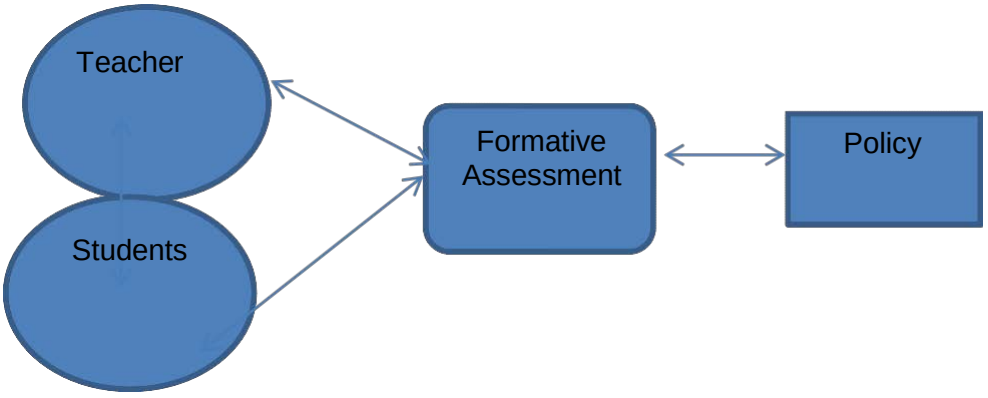
Also, the report has been presented with two main objectives in view as follows:

- To identify the specific areas of difficulty in Organic Chemistry for University students
- To identify the sources of difficulty in Organic Chemistry and possible remedies for University students

Theoretical Framework

The theoretical framework of this is based on a group of assessment theories of Zone of Proximal Development (ZPD) of Vygotsky's (1896 - 1934); Wood et al, (1976) Scaffolding theory and Dunn and Mulvenon model of academic success. The Zone of Proximal Development emphasizes difference between the students learning and level of achievement that could take place without any external human assistance and that which takes place when the student is given the necessary and appropriate assistance. Jean Piaget`s theory of lone learner nature of children and the scaffolding theory in conjunction with Vygotsky`s theory see the provision of learning experiences within the zone of proximal development of the students in order for them to advance in their learning endeavors.

It is clear from experience that students achieve meaningful learning through active involvement in the teaching-learning process and in fact, taking charge or control of their own learning. The try to make meaning of a learning task by knowledge construction and understanding based on belief and previously acquired knowledge.



Model of academic success Adapted from Karee E. Dunn & Sean W. Mulvenon (2009)

The purpose of assessment is hinged on taking assessment for learning, assessment as learning (formative assessments) and assessment of learning (summative assessment) with a view for policy formulations. The above model focuses on the interactive relationship elements of the model. This report views the assessment of students` difficulties in Organic Chemistry as a form of formative assessment with the purpose of providing possible antidotes to students learning difficulties in order to enhance future achievement in the subject.

Learning with comprehension should be the basis of every teaching/learning process and as a pivot of teacher-student-subject relationship. In other words, understanding and comprehension need to be emphasized and memorization or rote learning de-emphasized, while any assessment to be carried out should be such that measures comprehension instead of peripheral knowledge and information regurgitation. Teaching that brings about meaningful learning is usually built around key conceptual frameworks in any given subject and the students are expected to be assessed in their abilities apply the knowledge gained from the conceptual frameworks (scaffolds) in solving cognitive and life-related problems. This approach enables the assessor or teacher to determine the level of understanding and critical thinking abilities of the students concerning particular subject contents and topics. The advantage of this is that the outcome of the assessment could be used as:

(a) A way to identify students` learning difficulties in the subject
(b) An improvement strategy for student performance in the subject based on the assessment results
(c) A way to determine how the students learn. OECD/CERI, (2005) reported that one of the most effective approaches to take students through the skills of learning to learn is by the application of formative assessments.

It is therefore imperative that the teacher should provide opportunities for the students to useful information based on the result of assessments with the hope of helping them to discover their problem areas and finding the best possible ways of mitigating the challenges for increased meaningful learning. Such efforts through proper assessment and problem diagnosis will influence students` abilities for problem-solving and critical thinking.

RESEARCH METHODOLOGY

A total of 177 first year Chemistry students in 2011-2013 academic years participated in the study. The researchers took participants from different academic years using the Static group comparison quasi-experimental research design. The researchers also used four Organic Chemistry teachers during this research time. In other words, the study made use of intact classes of students in the University.

Course rationale in Organic Chemistry

Organic Chemistry I, course is primarily designed to offer basic understanding of structures, reactivities and synthesis of simple organic compounds. It deals with the relationships between structure and properties of organic compounds and is devoted to brief discussions of functional groups, their typical reactions and synthesis; mechanistic approach to reactions of organic compounds (substitution, elimination, addition, and rearrangement reactions). This will enable the students to understand the twin strategies of studying Chemistry of the millions of organic compounds by either classifying them according to the reaction types they undergo (mechanistic approach) or according to their functional groups (functional group approach). The course also introduces the concept of stereochemistry and stereoisomerism (configurational and conformational isomerism) and its importance in organic reactions. This

enables the students to appreciate the more subtle types of isomerism than the obvious structural (constitutional) isomerism.

Three major instruments and data collection methods were employed in this study. Relevant data from the participants of study were collected through the use of multiple instruments which were Document analysis, Questionnaire and Interviews**.**

To identify students' areas of difficulty, 177 Chemistry students' document analysis (students' achievement in 54 Organic Chemistry questions) in past three years were conducted. The Questionnaire was also used as tools to gather relevant information from the subjects of the study. Two sets of questionnaires (open ended and closed ended) were prepared to collect data on specific areas of difficulty in Organic Chemistry for University students and the sources and causes of such difficulties. Finally, Interviews were also used as data collecting instruments to get the views and opinions of students on identifying the specific areas of difficulty and the sources and causes of such difficulties in Organic Chemistry for University students. For the purpose 11 randomly selected students and four Organic Chemistry teachers purposefully chosen for the study were interviewed.

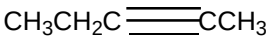
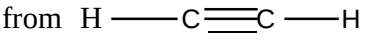
Analyses of Data

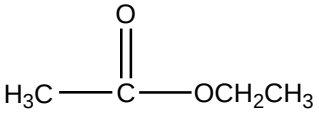
The data were analysed quantitative and qualitative analysis methods. The quantitative data were analysed by using descriptive statistics to describe the data in terms of the mean, and percentage. Analysis of the qualitative data involved document (examination/test scripts) analysis and thematic analysis of the interview data.

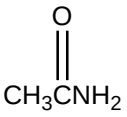
Results and discussions

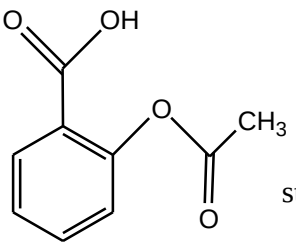
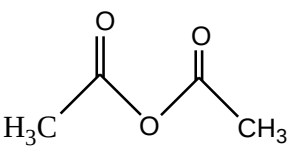
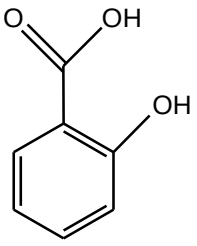
In order to understand areas of difficulty for students in Organic Chemistry, the researchers conducted document analysis (students' achievement on some Organic Chemistry topics) of 177 students; distributed questionnaire; and interview schedule for year II and year III Chemistry students.

Student participants were tested at the end of each of the research topics. For example, one of the questions given to the students after the teaching of functional groups was `By showing step by step reaction mechanism, neatly synthesize the following compounds starting from the given molecules using any appropriate organic or inorganic reagents`:

A.  Starting from 

B.  Starting from CH_3CH_3 and CH_4

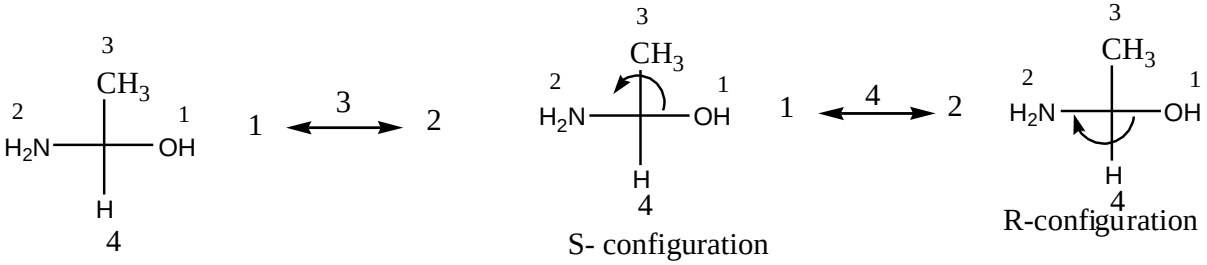
C.  Starting from CH_3CH_3 and CH_4

D.  starting  and 

Analysis of the students` scores for this question showed that out of 177 students, 164 (92.65%) of them, could not give appropriate and right answers as required. In order to give right answers for these questions, students should primarily, be able to draw reasonable and acceptable structural representations of organic molecules; understand the modern bonding concepts in organic compounds and their influences on properties of the compounds; and recognize various common organic functional groups and the chemical properties of each functional group. A good understanding of the properties of each functional group makes it is easy to determine the preparations and reaction mechanisms of common organic functional groups. Unfortunately, most of the students' answers showed lack of organization (coherence), and also without algorithms or step by step problem solving approach. Many of them could not show any form of or correct integration of concepts to be observed in their answers. This showed that students have difficulty in understanding functional groups Chemistry and so they were not able to address the questions with appropriate answers.

As part of stereochemistry topic, students learnt that two molecules which contain the same atoms with identical bond arrangements may have unique three dimensional structures (stereoisomers). Such molecules have the same physical characters, the same connectivity, yet they are spatially unique. The students also learnt the properties of such molecules and how to solve related problems such as whether two molecules are identical or not, as well as propose methods to transform one spatial configuration into the other. They were then tested with the following question:

`*Assign the R or S configuration to the following molecules in accordance with the sequence rule and interchange rule*`, and the students expressed some difficulties.



S- configuration

R-configuration

In order to give the configuration for the molecules given above majority of students started from 1 and moved to 2 through 3 rather than starting from 1 and move to 2 through 4. It should be noted that the number 4 is found at the rear side of the chiral carbon. The document analysis of the students` notes and papers indicated that 158 (89.26%) out of the 177 students had difficulty in visualizing and addressing the spatial orientation of the given molecule. This shows that students have difficulty in visualizing molecules in three dimensional structures.

In another question: `*Write structural formulas for the most stable conformation of each of the following compounds and explain why it is more stable than the other: **(a)**. trans-1-tert-Butyl-4-methylcyclohexane **(b)**.cis-1-tert-Butyl-4-methylcyclohexane*`, it was found that 152 (85.87%) of the 177 students failed to give the appropriate structural formula for the most stable conformation and to logically answer why it is the most stable compared to other structure. Majority of students have difficulty in identify the axial and equatorial positions for different conformations of di-substituted cyclohexane such as cis-1-tert-butyl-4-methylcyclohexane or trans-1-tert-butyl-4-methylcyclohexane; in determining and in writing the most stable structure; and in explaining why trans-1-tert-butyl-4-methylcyclohexane is more stable than trans-1-tert-butyl-4-methylcyclohexane.

In general, we can conclude from the above document analysis of students` achievement in stereochemistry topic, that many students have difficulties in visualizing structures of stereoisomers in three-dimensional forms; in relating three-dimensional with two-

dimensional shapes; in giving nomenclature of Enantiomers (R-S) system; and in explaining stability of different configuration of molecules and in other related questions.

In order to understand the nature of organic reaction type questions, students should be able to distinguish whether the given reaction follows mechanisms of addition, substitution, elimination and rearrangement reactions; and employ stereo-chemical considerations when analysing mechanisms and transformations. For example; for questions prepared under these topics such as *`Dehydration of 3, 3-dimethylbutan-2-ol results in the formation of 2, 3-dimethylbut-2-ene as the major product. Write the equation and show the mechanism of reaction clearly.* (*Hint: dehydration of 3, 3-dimethylbutan-2-ol occurs under acidic conditions to form an alkene*)`.

The students were expected to be able to write the appropriate chemical formula of 3, 3-dimethylbutan-2-ol, identify the chemical properties of each functional group found in this structure, identify its stereo-chemical aspects of the molecule, the nature of reagents and under what conditions they are used (temperature, nature of catalyst used, etc.), and identify the types of reaction mechanism it should follow (whether addition, substitution, elimination or rearrangement reactions). It was found that only 11 students (6.21%) out of 177 gave appropriate answer (3/3); 35% (62) students out of 177 gave sufficient answer (2/3) while 104 (58.75%) students scored 1 and less than 1 out of 3. This showed that students have difficulty in giving appropriate answers in organic reaction and mechanisms topics. Generally, the survey of students' opinion indicates that the most difficult topics in Organic Chemistry were organic reaction, synthesis and mechanism. The document analysis also proved the claim that students have difficulty in solving organic reactions, synthesis and mechanism type questions.

The above findings are similar to some other research reports. As O'Dwyer (2012) reported, Organic Synthesis, Mechanisms, Instrumentation and Functional groups were identified as difficult topics for Irish secondary school students. The other research done in identifying areas of difficulty in Organic Chemistry reported Organic Synthesis involving carbonyl compounds, Aldehydes and Ketones, Carboxylic acids and esters, Hydrocarbons: aliphatic and aromatic, (Johnstone, 1981; Childs and Sheehan 2009); Preparation of Organic compounds, Reactions and Reaction mechanisms (Bojezuk 1982); Organic Synthesis involving aromatic compounds, Organic Instrumentation (NMR) Ratcliffe (2002); as challenges to undergraduate Chemistry students in linking 2-D and 3-D representational levels (Gilbert 2005; Michael Corrin, *et al.*, 2013).

Students' attitudes towards learning difficulties of Organic Chemistry

To identify difficult topics and to identify the sources in Organic Chemistry, the researchers distributed closed-ended and open-ended questionnaires to students and Organic Chemistry teachers. The Likert scale was employed for open-ended questionnaire, which had five levels of responses ranging from strongly agree to strongly disagree. On analysis, the scale was further rescaled or modified into three for the sake of convenience. If the average indicated was above 3 (strongly agree and agree), it was taken as a positive statement and if it was below 3, then it indicates negative response and opposes the idea in the given statement. Therefore, the number 3 was considered as neutral, neither positive nor negative and taken as undecided.

Table 1: Summarised Attitudinal Responses from Students on Organic Chemistry Learning Difficulties

S. No	Statements	% of respondents		
		positive	Undecided	Negative
1.	Organic Chemistry is difficult subject for me	80.79%	8.47%	10.73%
2.	Organic Chemistry concepts are very easy to understand and solve Organic Chemistry problems	5%	6.21%	88.7%
3.	I am very happy in my duration and achievement in Organic Chemistry course	22.1%	-	77.9 %
4.	Organic Chemistry teacher method of teaching is more attractive and helped me to understand Organic Chemistry concepts well	18.64%	9%	72.3%

The above Table shows that 143 (80.79%) of the 177 student-participants agree or strongly agree with the statement that *'Organic Chemistry is difficult subject for me'* and 157 (88.7%) of them disagreed with the statement that *'Organic Chemistry concepts are very easy to understand and solve Organic Chemistry problems'*. This shows that Organic Chemistry is difficult subject for students to comprehend; however, the reason for difficulty was not clearly addressed here. Furthermore, 77.9 % of the students showed negative attitudes and disagreed with the given statement: *'I am very happy in my duration in Organic Chemistry and in my achievement in Organic Chemistry course'*, and 72.3% of them proved to be of negative attitudes about the statement: *'Organic Chemistry teacher method of teaching (lecture method) is more attractive and helped me to understand Organic Chemistry concepts well'*. This shows that majority of the Chemistry students have negative attitudes towards the subject due to their teachers` teaching approaches, hence their low achievement that makes them unhappy and bored in their Organic Chemistry classes.

Reasons advanced by students for their negative attitudes towards Organic Chemistry

The students advanced several reasons as they answered the open-ended question *'Do you think Organic Chemistry is difficult subject for you? Yes or No;* then give reason for your answer. 83% of the students perceived and took Organic Chemistry as difficult subject to grasp. The most frequent reasons advanced for this question by the students were:

a) *Nature of the subject and topics(organic synthesis, mechanism and reaction) is difficult to comprehend;*

b) *Organic Chemistry teachers` methods of teaching are not attractive and appealing enough to address the nature of organic synthesis; and*

c) *Lack of interest in Organic Chemistry because it is a difficult subject.*

It was interesting to observe that even students who scored good grades in Organic Chemistry could not deny the difficulty and volatility of Organic Chemistry as a subject. Similarly interview results with the randomly selected students, showed the following responses and justifications from a few of them:

One of the students said:

"I don't want to remember the time I took courses in Organic Chemistry. For me, it was very challenging. I tried to study hard, but when I came back to solve Organic Chemistry exercises, really it was a very big challenge. All of my effort I put in the study became nothing. Wow…I don't want to remember it".

Another student responded thus:
"Organic Chemistry is a very interesting course. I am very happy if I successfully comprehend and perform well in Organic Chemistry. But, Organic Chemistry is generally very challenging, especially organic synthesis and reaction mechanisms. When I remember the nature of Organic Chemistry even in the future, I don't want to study it again".
Generally from document analysis; questionnaires; and interviews with the students and Organic Chemistry teachers, the researchers identified the following major areas of Organic Chemistry topics as difficult for students to comprehend:

Functional groups:

- Writing appropriate reactions for different functional groups,
- Writing correct methods of preparation/synthesis of different functional groups and
- Proposing mechanisms of reaction for different functional groups);

Stereochemistry:

- Visualizing structure of stereoisomers in three-dimensional;
- Relating three-dimensional with two-dimensional;
- Giving nomenclatures of Enantiomers (R-S) system as Cahn-Ingold-Prelog (CIP) sequence rules of Fischer Projections
- explaining stability of different configurations of molecules; and Conformational analyses in alkanes: Cycloalkanes: Cyclopropane, cyclobutane, cyclopentane and Cyclohexane

Organic reactions:

- Categorizing the types of organic reactions as SN_1, SN_2, E_1 and E_2 mechanism;
- Writing mechanism of reactions for substitution reactions, elimination reactions Addition reactions and rearrangement reactions.
- Differentiating and proposing mechanisms of reaction in Rearrangement reactions such as: Migration to electron deficient carbon; Migration to electron deficient oxygen; and Migration to electron deficient nitrogen
- Applications of Substitution Reactions, Elimination Reactions, Addition Reactions and rearrangement reaction

Reasons given by Organic Chemistry teachers
Considering the analysis of data from Organic Chemistry teachers` questionnaires and interviews, they all agreed on difficulty of Organic Chemistry for students in general. Organic Chemistry teachers have given the following reasons for students' low achievements and difficulty in Organic Chemistry at the undergraduate level:

- Majority of the students fail in high-level reasoning, problem solving and critical thinking skills and so they find it difficult to cope with the demands of Organic Chemistry;
- They have low intrinsic motivation to learn Organic Chemistry (they want to learn it through rote-learning and memorization rather meaningful learning);

- Students` poor background in visualizing Organic Chemistry molecular structures;
- Students expected too much help (spoon-feeding) from their instructors and teachers (they do not apply knowledge construction process);
- Low ability to view situations from different angles;
- There are no algorithms (step by step problem solving) for solving Organic Chemistry exercises such as mechanisms in their presentations; and
- The students tend to memorize Organic Chemistry concepts rather than understand the concepts deeply; therefore fail to apply them in new situations while solving exercises.

Organic Chemistry Teachers` Advice for Improvement in Teaching and Learning of Organic Chemistry

The teachers made the following suggestions in order to improve Organic Chemistry teaching and learning in Universities:

- High school Chemistry teachers and curriculum designers should encourage high schools students to follow algorithms for problem solving and critical thinking approach in Chemistry.
- Organic Chemistry teachers at all levels should design active learning approaches and integrate such into their classes wherever necessary.
- It was also suggested that Organic Chemistry teachers should use different models and animations while teaching to help increase students` visualization abilities in the subject.
- Organic Chemistry teachers should balance between students` learning experience and the course contents.
- Organic Chemistry teachers should understand students` areas of learning difficulties, design appropriate teaching approaches for them and interject wherever applicable.

Conclusion

Through empirical approach, this study has identified the following major areas of Organic Chemistry topics as difficult for students to comprehend: **Functional groups** (Writing appropriate reaction for different functional groups, Writing correct method for preparation/synthesis of different functional groups, and Proposing mechanism of reaction for different functional groups); **Stereochemistry** (Visualizing structure of stereoisomers in three-dimensional, Relating three-dimensional with two-dimensional, Giving nomenclature of Enantiomers (R-S) system as Cahn-Ingold-Prelog (CIP) sequence rules of Fischer Projections, explaining stability of different configuration of molecules; and Conformational Analysis in alkanes: Cycloalkanes: Cyclopropane, cyclobutane, cyclopentane and Cyclohexane); **Organic reactions** (Categorizing the types of organic reactions as: SN_1, SN_2, E_1 and E_2 mechanism, Writing mechanism of reactions for substitution reactions, elimination reactions, Addition reactions, and rearrangement reactions, **Differentiating and proposing mechanism of reaction in Rearrangement reactions** such as: Migration to electron deficient carbon; Migration to electron deficient oxygen; and Migration to electron deficient nitrogen, Applications of Substitution Reactions, Elimination Reactions, Addition Reactions and rearrangement reaction).

Furthermore, the study identified the following as sources and causes of difficulty of Organic Chemistry for students: Low level of high-level reasoning, poor problem solving and critical thinking skills; low intrinsic motivation to learn Organic Chemistry among the students; Students poor background in visualizing Organic Chemistry, students experience of learning of believing in spoon-feeding by their instructors, lack of algorithms for solving Organic Chemistry problems, and the tendency to memorize Organic Chemistry concepts rather than understanding the concepts deeply to be able to apply such in new situations. Finally, the researchers identified the **reasons** for students' difficulties in Organic Chemistry at the University level to be hinged on: Chemistry teachers` teaching methods; Nature of the subject itself; and Students experience of learning.

Recommendations

The following recommendations stand out on how to ameliorate the difficulty level experienced by Organic Chemistry students in the Universities:

- Organic Chemistry teachers should understand students` learning difficulties in Organic Chemistry topics and design appropriate instructional strategy and approach for them with relevant interjections wherever applicable.
- High schools Chemistry teachers or curriculum designers should be encouraged students to use different models which can help them to develop visualization abilities in the students.
- Students should be encouraged to follow algorithms for problem solving in Chemistry. This will further enable them to see the study of Organic Chemistry as a process.
- Organic Chemistry teachers should design active learning approaches and activities and integrate them with their usual classroom activities wherever necessary.

References

Anne O' Dwyerand Peter Childs, (2012). Identification of the difficulties in teaching and learning Chemistry in Ireland and the development of a second-level intervention program to address these. A paper submitted to University of Limerick for degree of doctor of philosophy. Pg 60-113.

Anne O' Dwyerand Peter Childs, (2010). Second Level Irish Pupils' and Teachers' View of Difficulties in Organic Chemistry. IOSTE Mini-Symposium June 2011, 19-21.

Bhattacharyya, G. and Bodner, G. M. (2005). It gets me to the product: How students propose Organic Mechanisms', *Journal of Chemical Education*, 82(9), 1402-1406

Bowen C.W. and Bodner G.M., (1991). Problem-solving process used by graduate students while solving task in organic synthesis, *International Journal of Science Education*, 13, 143-158.

Childs, P. E. and Sheehan, M. (2009). What's difficult about Chemistry? An Irish perspective, *Chemistry Education Research and Practice*, 10, 204-218.

Dunn, K.E. and Mulvenon, S.W. (2009). A Critical Review of Research on Formative Assessment: The Limited Scientific Evidence of the Impact of Formative Assessment in Education. *Journal of Practical Assessment, Research and Evaluation* Volume 14, Number 7, March 2009

Ellis, R. (1994). The Study of Second Language Acquisition. Oxford: Oxford University.

Ferguson, R. and Bodner, G. M. (2008). Making sense of the arrow-pushing formalism among Chemistry majors enrolled in Organic Chemistry, *Chemistry Education Research and Practice*, 9, 102-113.

Gilbert, J. K., (2005). Visualization: A metacognitive skill in science and science education. In J. K. Gilbert (Ed.), Visualization in science education (pp. 1e27). Dordrecht, the Netherlands: Springer.

Girija S S and Deepa S. M., (2004). University students Performance in Organic Chemistry at undergraduate level: perception of instructors from universities in the SADC (Southern African Development Community) region: Department of Chemistry, University of Botswana. Presented at *SAARMSTE Conference* in January 2004 at Cape Town. South Africa. (http://khimiya.org/volume14/efficiency.pdf, assessed on July, 6, 2012)

Habraken, C. L., (1996). Perceptions of Chemistry: why is the common perception of Chemistry, the most visual of sciences, so distorted? Journal of Science Education and Technology, 5(3), 193e201

https://www.eduweb.vic.gov.au/edulibrary/.../assessment_current_per.pd... (2005) Current Perspectives on Assessment; Assessment and Reporting Unit Learning Policies Branch Office of Learning and Teaching, September, 2005, Accessed 14/10/2015.

Ingo Eilks and Avi Hofstein, (2013). Teaching Chemistry – A Studybook. A Practical Guide and Textbook for Student Teachers, Teacher Trainees and Teachers: Sense Publishers AW Rotterdam, The Netherlands. Pg 8-10.

Izzet Kurbanoglu N., Yavuz Taskesenligil and Mustafa Sozbilir, (2006). Programmed instruction revisited: a study on teaching stereochemistry. *Chemistry Education Research and Practice*, 2006, 7 (1), 13-21

Johnstone, A. (1991). Why is science difficult to learn? Things are seldom, what they Seem. *Journal of Computer Assisted Living*, *7*, 75 – 83.

McCormick, R. and Li, N. (2006). Evaluation of European Learning objectives in use.

Michael Corrin, Melanie Burger, Ghislain Deslongchamps, and Jodie Jenkinson, (2013). A New Web-Based Resource of Interactive, Animated Organic Chemistry Reactions. Lab3D is an online resource of animated Organic Chemistry reactions. http://www.ccce.divched.org/P10Fall2013CCCENL. Assessed January 22, 2014

Millar, R. (1991). 'Why is Science hard to learn?' Journal of Computer Assisted Learning, 7, 66- 74.

OECD/CERI, (2005). *Formative Assessment – Improving Learning in Secondary Classrooms*, OECD Publishing

Simsek, U. (2009). The effect of Animation and cooperative learning on Chemistry students` academic achievement and conceptual understanding about aqueous solution, *World Applied Science Journal.* 7 (1), 23-33.

Sirhan G., (2007). Learning Difficulties in Chemistry: An Overview. *Journal of Turkish Science Education:* Volume 4, Issue 2, pp. 1-19.

Stieff, (2007). Mental rotation and diagrammatic reasoning in science Curriculum and Instruction. *Learning and Instruction*, USA. Vol. 17 pg 1-16.

Uttal, D. H., and K. O. Doherty. (2008). "Comprehending and Learning from 'Visualizations': A Developmental Perspective." *Visualization: Theory and practice in science education*: 53-72.

Vygotsky, L.S. (1962). *Thought and Language*. Cambridge, Ma, MIT Press & Wiley.