ENHANCING STUDENTS' PERFORMANCE IN ORGANIC CHEMISTRY THROUGH CONTEXT-BASED LEARNING AND MICRO ACTIVITIES- A CASE STUDY

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ABSTRACT

This study explored high school students' reasoning patterns towards conceptual change and academic achievement as they learned to construct concepts in basic organic chemistry through everyday experiences for life. Analysis revealed a number of patterns by which students constructed ideas in formal and contextual aspects. A formal procedure used to teach and learn organic chemistry for life is presented. Tasks for context-based problem solving procedures were designed using combinations of familiar contexts and concepts based on the students' syllabus. In this study the application of concepts like addition reactions, saturation, unsaturation, electronegativity, molecular formula, molecular structure, bonding, polarity and electronegativity were expected. Students' reasoning patterns after an intervention showed that they could apply their gained concepts to solve problems in different contexts. Results were explored and implications for context-based teaching and learning assessed.

Keywords: Analytical, conceptual change, context-based, remediation.

INTRODUCTION

A main goal of chemistry education is to guide students in building mental models of chemical phenomena and ensure close congruence to scientifically accepted models, as their higher-order thinking skills are unfolded and challenged (Aksela, 2005). One area of chemistry where students demonstrate a lot of challenges with respect to building authentic mental models is organic chemistry. Adequate understanding of organic chemistry is a pre-requisite for many graduate and professional programmes in human care. It is a key to the development of new products in the society and for improving on many more of them that we have become dependent on. It is the basis for the production of food flavours, plastics, clothing, car tyres, fuels, cement, pharmaceuticals and house cleaning agents. It is also important in the investigation and security agencies.

According to Coll(2014) students consider organic chemistry a big hindrance to the study of chemistry as a discipline. Several factors affect students' poor performance. Some of these have been known to include their own preparedness, teacher's content knowledge and preparedness, environmental/social factors (including the home and school), language, and many more (Korau, 2006). In Korau's study, he particularly identified poor conceptual foundation, students' disinterest, incompetent teachers, large class sizes and psychological fear for chemistry as prominent causes for the observed poor performance of Nigerian students. In some cases, loss of interest and attrition could be related to negative experiences such as poor grades, fear of laboratory accidents (Hanson & Acquah, 2014), fear of engaging in and not getting positive results during practical activities, minimal engagement with resources and teachers' incompetent pedagogical content knowledge (Barr, 2008). In Ghana, Hanson (2016; 2014) identified students' inabilities to understand the nature of matter and how to connect among the three representational levels of matter as the main limiting factor in their study of chemistry. Students are often unable to understand thoroughly these representations and so form faulty and weak basis for further study of chemical phenomena; especially in organic chemistry.

Often, poor performance is blamed on students because of their low retention capabilities, low motivation, low achievement, inappropriate social groups in school, and parental issues. Nevertheless, other factors such as teachers also play a significant role during the teaching and learning process as they influence students' attitudes towards the study of chemistry. Their behaviour can affect students' performance(Yara, 2009). Thus, more interactive and engaging environments where enthusiastic teachers facilitate and do not bear too much on students' constructive activities could enable students to feel free, while they take responsibilities for their actions, and learn to construct their own informed knowledge.

Chemistry is a discipline that contributes to uplift humankind's living standards through the provision of health and other social amenities. It is one discipline upon which technological advancement is hinged. Thus, chemistry education, and organic chemistry education in particular, must be every country's gateway to technical and industrial growth. This can best be done through context-based learning approaches (CBL) so that the linkages between chemistry and society, as well as research and practice, can better be appreciated. CBL approaches have affected students' interest and learning outcomes over the last 40 years in many countries (Broman & Parchmann, 2014; Fechner, 2009). This is because CBL combines chemistry content with familiar contexts to make chemistry problems more authentic and realistic; it inherently demands complex thinking and higher order literacy (Hofstein, Eilkis, & Bybee, 2011). It therefore provides an interconnected content knowledge. According to the context-based learning theory, individuals make associations and form deep impressions of concepts based on everyday life examples. What distinguishes context-based learning from other learning theories is the adopted constructivist approach with social underpinnings. It intends to raise students' attention to the science in everyday events so that they realise the association between real life issues and science (Bennett, Hogarth, & Lubben, 2003). Employing context-based education is important in building sound concepts. It also helps to answer the question on why one has to learn a particular topic or discipline. Here, students learn in a manner that makes them associate their own experiences and lives with what they learn in the chemistry classroom. If they are conscious of the fact that what they learn will impact on their lives and that of others, and the society at large, then it will positively affect their conceptual attitude, and change processes, and subsequently their academic performance (Kirman Bilgin & Yigit, 2017).

In Ghana, the teaching of organic chemistry is taken seriously and so all secondary school children learn some amount of it as well as its many benefits to mankind. However, their academic performance in chemistry in general has been poor. In-depth studies into their poor performances by educational researchers and the West African Examinations Council (WAEC) have been traced to about five main factors. One of them is their inability to answer questions based on organic chemistry in particular coherently and from a conceptual basis (Hanson, 2014; WAEC, 2014; WAEC, 2015). Some do not attempt to answer such questions at all. Others make feeble attempts at solutions.

One other weakness was traced to the non-performance of practical activities, especially in organic chemistry, which was attributed to lack of science equipment and other working consumables, like organic solvents. It was gathered that some students deliberately avoided practical work because they deemed working with the often volatile and flammable organic solvents as dangerous and prone to catch fire (Hanson & Acquah, 2014). There is adequate evidence that laboratory instruction is an effective and efficient process to attain some of the goals for teaching chemistry, as activities have the potential to promote positive attitudes and provide students with opportunities to develop cooperative and communication skills, which enhances higher-order thinking. Besides, it avoids monotony (Hofstein & Mamlok-Naaman, 2007). Thus, the use of small scale science equipment in experimentation was suggested since they are cost-effective, and require the use of minimal solutions which cannot result in dangerous and harmful explosions (if they even occur). Besides, they are fun to work with, safe for the environment, safe for users, and make it possible for students to perform activities so that they develop the required learning skills (Hanson, 2014).

Yet another identified factor for students' poor performance in chemistry in general is the teaching approach that is employed by most teachers. Most teachers employ the lecture or traditional method. In the traditional teaching approach, which is common, students are passive recipients, while in active learning approaches such as context-based learning, they assume an active position, as they learn about themselves and their environment. Tasks that require student's active involvement stimulate learning.

One major cause that was recently identified as an underlying reason for students' nonchalance towards science was the non-connectivity between science and one's personal life (Bilgin, Yurukel, & Yigit, 2017). Students are incapable of associating science concepts with everyday life and ask about the importance of certain topics and disciplines in their lives, when teachers introduce them in their lessons. They may be comfortable learning about acids in fruits and carbonated drinks, which they are familiar with in their daily lives, but not appreciate spending time to learn about other topics such as chemical equilibrium (Locaylocay, 2006), or the principles on which the arrangement of electrons is based. They find them distant, far-fetched and abstract. They often ask, 'why do I have to learn this? What is its importance?' (Stolk, Bulte, De Jong, & Pilot, 2012). We same several years back because we could see no link between the hard core (theoretical) chemistry that was learned and our everyday life experiences. This 'non-connectivity' affected our attitudes towards certain science disciplines back then and continues to affect students now. The deliberate attempt by teachers to let students see the importance of what they learn in their everyday lives raises students' interest and motivation (Broman & Parchmann, 2014). Teachers can begin their lessons by asking questions related to everyday life events. The context of the properties or answers could then be steered to the classroom and its scientific or chemical aspect emphasised through individual, small group and whole class discussions.

Students' own attitude is also another factor that affects their performance in their study of organic chemistry. In chemistry education, attitude is an important factor that affects students' achievement. Students with positive attitudes towards science are successful in the classroom as they are able to form sound concepts and thereby perform better academically (Koballa & Glynn, 2007). The use of appropriate resources, good assessment processes, and teachers' command (articulation) over the content also affects students' attitudes. Teachers, by their attitudes, act as engineers of progress and change towards academic work (Adesoji & Raimi, 2004). They must therefore develop context-based instructions so as to draw the attention of students to their environment. Contexts have to be used to connect science with students' lives in order to provide a frame in which concepts can be learned and applied on a 'need-to-know' principle. In this way, students will see the benefits of what is taught in schools.

Eliciting students' individual capabilities, intelligence and creative thinking can be achieved through deliberate student-centred instruction and structured laboratory activities. Students have to 'do things' amidst guidance (teachers' facilitation) in order to construct their own authentic sequenced ideas. In this vein, equipped laboratories would be required for hands-on activities. However, acquisition of laboratories is expensive and so acquiring micro chemistry equipment could provide the same enabling environments as suggested by Tantayanon (2016), Suparson (2015), Hanson (2014) and Mafumiko (2008). Micro science equipment comes in small lunch-size boxes which are entire laboratories on their own. With the 'box laboratory', students become active as they observe, manipulate, analyse, reflect and process ideas to draw conclusions about chemical and natural phenomena. The exposure, nurturing, and development of such manipulative, process, and concept skills in such enabling environments cause permanent learning (Hanson, 2017). Findings from reviewed studies report significant differences between students taught with constructivists' paradigms through worksheets, conceptual text, models, animations, micro science equipment, and those taught in the traditional way (Hanson, 2017; Justi, Gilbert, & Ferreira, 2014; Ozmen, Demircioglu, & Demircioglu, 2009; Demircioglu, Ayas, & Demircioglu, 2005).

Conducting small scale organic chemistry activities through the use of micro kits have been known to enhance students' conceptions not only in South Africa (Sebuyira, 2001) but also in Ghana (Hanson, 2014), Mozambique (Kombo, 2006), Tanzania (Mafumiko, 2008) and most of the Asian countries including Thailand, Japan, Taiwan and Indonesia (Tantayanon, 2016; Supasorn, 2015). When it was introduced to undergraduate students in a Ghanaian university who also had misconceptions about organic chemistry, it was found to enhance their cognition and academic performance (Hanson, 2014). Chemistry students who used them in hands-on activities made conceptual gains as they overcame their conceptual challenges in principles that guided the study of organic chemistry. In this way they were able to engage in a kind of reality as they observed the causes and effect of phenomena in different variables. These concrete illustrations enhanced their concept formation and subsequently, academic performance. The micro activities enabled students to verbalise, discuss, and explain scientific processes, as they worked together. Thus, engaging students in context based learning (CBL) activities with respect to the constructivist paradigm, using the micro chemistry equipment as a tool, was adopted in this study to affect students' attitudes and understanding of basic chemistry concepts.

The purpose of this study was to employ context-based problems that could demand higher order thinking among high school students even as they connected classroom chemistry to their everyday lives and the chemical society in which they live. Here, context will imply the social setting in which content would be framed or displayed. The context could be in the form of a theme, subject, problem story, a market scene, and meal time scene or in-class activity framework. Thus, the causes of their poor performance in organic chemistry were identified and remediation offered through an analytical and reflective platform, using everyday life situations and micro equipment activities as a channel to achieve the set goals. The questions that guided the study were:

1. What are some of students' own ideas and misconceptions about organic chemistry?
2. What factors influence their poor performance in organic chemistry?
3. To what extent do the identified factors affect their performance?
4. To what extent do teachers' attitudes towards their teaching of organic chemistry affect students' performance?
5. What impact would the use of context-based learning intervention have on students' attitudes and performance in organic chemistry?

ISSN 2056-5852

METHODOLOGY

A case study, with an in-class action research approach was adopted as it sought to improve on a situation that affected a whole class in a dynamic and collaborative manner. Action research provides room for improvement during teaching and learning. It is associated with a cyclic nature and allows both researchers and participants to continually learn from each other. This provides opportunity for continuous reflection as it fosters deeper understanding of a situation with conceptualization and moves through several interventions and evaluation phases. It has the ability to commit research and practice to solve a problem by improving classroom practice as well as student learning. Besides, it allows for professional growth and development of teachers. A case study design allows for in-depth analysis of a prevailing situation rather than a 'sweep-over' as observed in statistical surveys. It is also useful for testing whether a theory or model actually applies to phenomena in the real world. This design was carved on a contextual platform along which the investigation in question was developed.

The sample for the study was 121 students and four (4) chemistry tutors who were purposively chosen for the subject under study. These selected participants were easily and readily available, while they met pre-established criteria for the study: students who studied under work-driven teachers, exhibited apathy towards their studies, and so underperformed in their study of organic chemistry, as well as teachers who were burdened with timeline curriculum/syllabus-completion expectations and unenthusiastic students. Too large a sample from the catchment area could be unwieldy while too small a sample in the study school could be an underrepresentation and not give a true reflection of the identified problem.
A context-based pre-intervention test (sample shown as part of Appendix A) was administered to assess students' entry point in the study. A test of practical knowledge was also administered (appendix B). This test their application of basic organic chemistry concepts such as nomenclature, determination of their elemental constituents, purity of compounds, chemical bonding, reactions, solubility and structural representations. These topics were framed by three different contexts- personal, environmental, and professional, because a proposed intervention was to be structured along that line. An 8-week intervention structured on the said framework was offered to the students after analysis of their pre-intervention test. This was supported with MCE activities. A post-intervention test (like Appendix A) was conducted to ascertain the impact of the intervention afterwards. This was to investigate if real life contexts could affect students' attitudes towards the study of chemistry. In designing the questions, issues regarding both context and content were integrated so as to be able to assess how the two parts could influence students' responses and general achievement. A 14-item questionnaire specially designed for teachers and a 10-item questionnaire for students were administered to the participants to assess their attitudes towards the teaching and learning of organic chemistry. They were designed to elicit participants' attitudes and interest towards the teaching and learning of organic chemistry. The reliability of the teacher and student questionnaires was 0.73 and 0.84 respectively. Instruments employed for data collection were pre-intervention test, post-intervention test, and questionnaires, which were attitude-based for students. Students' conceptions and performance were gathered through the intervention tests. The impact of the intervention was evaluated from a post-test that comprised of a social based chemistry question and a test of practical knowledge. A sample of the micro chemistry activity is shown as Appendix B. Means and percentages were used to analyse the tests and questionnaires.

Interviews were employed to assess students' true impressions about the use of context-based problems on worksheets and MCE activities. This is because written texts (tests and questionnaires) show mute evidence from participants and could be interpreted wrongly. Interviews truly express participants' sentiments. The interview was also used to triangulate obtained data from tests and questionnaires and to corroborate them. The semi-structured interview sessions were audio recorded and transcribed. The interview schedule is presented as Appendix C.

In order to validate the research instruments, the researcher consulted the SHS syllabus, prescribed texts and past national examination questions in chemistry for students. The purpose was to gain insight into what learners were expected to conceptualise, in order to develop the instruments accordingly. They were later cross checked by colleagues for content and construct validities and improved upon. The reliabilities of the instruments were determined using Pearson's test-retest correlation coefficient. After these checks a pilot study was conducted for further modifications. In order to analyse students' application of chemistry concepts in their responses certain keywords such as 'because' and 'therefore' were expected in logical sequence. The total marks for the test was 100. Data obtained from the tests are presented as in Tables. Table 1, shows students' polled performances in the pre-intervention test.

Table 1: Pre-intervention test results

Class boundary	Frequency (F)	Class mark (x)	Fx
0-19	32	9.5	304
20-39	47	29.5	1386.5
40-59	29	49.5	1435.5
60-79	9	69.5	625.5
80-99	4	89.5	358
Total	121		4109.5

Mean = 33.9%

From Table 1, majority of the students (108 out of 121) performed below 50% on the pre-intervention test. Only 13 students performed well. An analysis of their answer sheets showed that they had naive and disorganised ideas about organic chemistry concepts, especially their nomenclature, structural representations and the principles of bonding.

Some of their naive conceptions and representations were:

1. Lack of knowledge about the tetravalent nature of carbon
2. The covalent nature of organic compounds
3. Reactivity of organic compounds and derivatives with common functionality
4. Misconceptions about polarity of organic compounds
5. Inadequate application of terms like electronegativity, electron affinity, polarity, non-polarity
6. CH_3COOH drawn and named methanoic acid because there is only one observable methyl or carbon. The other carbon was functionality and not part of a stem.

As observed in Table 2, after the intervention many students performed well in the post-test.

Table 2: Post-intervention results

Class boundary	Frequency (F)	Class mark (x)	Fx
0-19	13	9.5	123.5
20-39	29	29.5	855.5
40-59	39	49.5	1930.5
60-79	21	69.5	1459.5
80-99	19	89.5	1700.5
Total	121		6069.5

Mean = 50.16%

From Table 2, only about 81 out of 121 students performed poorly in the post-intervention test, an improvement of 27 students over the pre-intervention test. A total of 40 students performed creditably well, out of 121 students.

The factors that affected both teachers' and students' attitudes (in no particular order) were also analysed and presented in simple percentages (from a Likert scale of 1-5 for strongly not agree to strongly agree). The teachers' responses are shown in Table 3. Agree and strongly agree were clustered as agree, while disagree and strongly disagree were clustered as disagree.

Table 3: Teachers' pre-questionnaire

Items	Disagree	Not sure	Agree
1. I have an affable relationship with my chemistry students	0	1	3
2. Students engage very actively with me in class by making contributions towards the lesson	3	0	1
3. I use diverse teaching methods in class	2	1	1
4. I use the lecture method as I have to complete the syllabus	1	0	3
5. I make references to everyday events in my lessons	4	0	0
6. I engage students in organic chemistry activity as expected	2	1	1
7. I complete the organic chemistry section of the syllabus	3	1	0
8. My students enjoy organic chemistry	4	0	0
9. I use activity-oriented teaching approaches	2	1	1
10. Hands-on activities are important in concept building	0	1	3
11. I use the question and answer method	2	0	1
12. The organic content is overloaded for the period of study	0	0	4

13. *In a few words, give your impressions about the CBL and MCE activities and lessons.
14. *Any other comments?

From Table 3, teachers did not base their teaching on everyday events. They were aware that their students did not enjoy their lessons and did not have an amiable relationship with them in class. They intimated that the coverage of the organic chemistry syllabus was expansive and so they were unable to teach the entire content. The teachers' responses in the post-questionnaire (which contained the same set of questions as in Table 3) did not change much. The only differences were in items 13 and 14, where their impressions about the newly introduced CBL and MCE, as well as other comments were sought through a free-response item. In their free responses they mostly provided answers that bordered favourably on the newly introduced approach and tool.

Data gathered on students' attitudes prior to the introduction of the CBL approach are presented as Table 4 with the same interpretation of measures for polled agree, not sure and disagree. Agree and strongly agree were clustered as agree, while disagree and strongly disagree were clustered as disagree.

Table 4: Students' pre-intervention questionnaire

Items	Disagree	Not sure	Agree
1. I enjoy my organic chemistry class	86	12	23
2. I like my organic chemistry teacher	97	6	18
3. I like the teacher's teaching style	95	4	22
4. I do not understand what the teacher teaches	18	11	92
5. I sometimes do not attend class because I do not enjoy the organic chemistry lessons	61	17	43
6. The teacher engages us in practical activities	102	0	19
7. Teacher demonstrations of what he teaches will be useful	78	15	28
8. The inorganic chemistry content is adequate to learn in the given term	109	12	0
9. The teacher uses stories or everyday life events to help me to understand the importance of what I learn	98	4	9
10. Knowing the importance of what I study will make me learn more	8	3	101

An overview of responses in Table 4 suggests that students in this study did not enjoy their organic chemistry classes (86) as many of them (95) did not like their teachers' teaching styles or the teachers themselves (97). Neither were they engaged in practical activities. They preferred to know the applications of the theoretical knowledge that they acquired in class, which was lacking, and so sometimes deliberately stayed away from class. The assertions raised in their responses were verified in an interview session for their veracities.

The student assertions presented in Table 4 about their impressions of their teachers and their own attitudes towards the study of organic chemistry were assessed again after the introduction and implementation of the CBL approach. Their impressions changed. They had more positive impressions about their chemistry teachers and attitudes towards their study of organic chemistry. Their impressions are presented as Table 5.

Table 5: Students' post-intervention questionnaire

Items	Disagree	Not sure	Agree
1. I enjoy my organic chemistry class	26	4	91
2. I like my organic chemistry teacher	47	4	72
3. I like the teacher's teaching style	29	3	89
4. I do not understand what the teacher teaches	86	7	28
5. I sometimes do not attend class because I do not enjoy the organic chemistry lessons	74	21	26
6. The teacher engages us in practical activities	10	0	111
7. Teacher demonstrations of what he teaches will be useful	62	43	16
8. The inorganic chemistry content is adequate to learn in the given term	71	20	30
9. The teacher uses stories or everyday life events to help me to understand the importance of what I learn	14	2	105
10. Knowing the importance of what I study will make me learn more	4	0	117

The positive impressions about the study of organic chemistry were confirmed by students' responses in a follow-up interview. A few of their assertions on the MCE are presented below:

- *The MCE gave very rapid results. Fast completion.*
- *It was fun to work with. No fear of a liquid splashing from the tiny container over you.*
- *I am sure since we save on chemicals teacher will make us do more activities often.*
- *The equipment was easy to handle; without fear of breakage.*

Some of their impressions about the CBL approach are also shown below:

- *I didn't think that there was so much chemistry in things that we did.*
- *Now, I think of myself and the environment when we do activities. For example, how will the environment suffer if I use too much of something; and how it will hurt me too.*
- *I can see the importance of science in many things that I do. Everything is chemistry.*
- *The real life problems were always very interesting to solve. It was like we were not even doing the difficult chemistry.*

DISCUSSION

From students' activities and responses as well as the teachers' responses, it became clear that several factors influenced the teaching and learning of organic chemistry in the school studied. Teachers and students' behaviours were uncompromising. Students and teachers alike did not show much commitment towards their intentions for being in that course of study. The students initially exhibited apathy, truancy, poor retention of basic concepts and could not apply what they remembered, as per their output in especially the pre-test. Neither could they represent structural formulas, much less their isomers in two-dimension. In organic chemistry the retention and application of basic concepts is relevant for successful progression towards building conceptual frameworks. They also demonstrated limited scientific vocabulary and so could not use appropriate scientific expressions to describe theoretical and observed events. Practical activities were hardly organised due to non-available and inadequate equipment, coupled with lack of time for practice. About 90% of them stated that they were not interested in organic chemistry lessons; thus their performances were quite poor. According to Coll(2014) such entrenched positions could contribute to students' failures. Inability to remember concepts previously taught could be traced to students' nonchalant attitudes. Majority of these students did not attend class. Some reiterated in an interview session that the content to be covered was too much and so did not want to bother to begin at all as they knew that they could not cope with it. They wanted to rather concentrate on the physical and inorganic aspects of their chemistry course.

The teachers' attitudes in particular towards organic chemistry could be said to have affected the students' academic performance. From the questionnaire teachers used inappropriate teaching methods, were unfriendly, and passed scathe comments. This non-chalant and non-committal attitude put students off. Some of these were:

Organic chemistry is not for kids.

This course is for those who intend to be doctors or pharmacists and not for everyone.

You must be a 'break' (genius) to study this.

Majority of teachers used the lecture and question and answer methods. They spent less interactive sessions with their students and conducted virtually no hands-on activities for them. Only one teacher, out of four, conducted practical lessons, which were more or less, often in the form of demonstrations. Nevertheless, they all admitted that laboratory or hands-on practice was important in enhancing the understanding of scientific principles. Organic chemistry was part of the third year syllabus and so was often not taught at all as teachers were busy preparing students in other 'easier' topics for their examinations. Some students admitted that teachers hardly taught organic chemistry. They appeared incompetent when they ever taught them. Some teachers also acted unprofessionally by passing unsavoury comments about their students. According to Yara (2009) teachers' attitudes and methods greatly influence students' attitudes towards topics or subjects taught in schools. Both teachers and students' impressions and attitudes changed shortly after the introduction of the CBL approach and MCE activities.

When the CBL approach was introduced, attitudes and competence of students improved. In the lessons, a problematic environmental question or real life situation was presented at the beginning of the lesson. This often required recall of previous ideas in order to make predictions about expected results. This enabled a link to be formed between already learned concepts and expected ones to be learned. This encouraged vigorous healthy class discussions, as often students saw themselves 'out of class' in more friendly environments before they gradually dwelt on the chemical principles in the context. In a way, they moved onto the chemistry platform from familiar environmental background stories. Then, they had to go back to assess the impact of chemistry on these familiar environments. This highly encouraged class attendance (though records of attendance are not shown in this report). They also exhibited a lot of collaboration and communication skills, as observed by Hanson (2014) when undergraduate students engaged in micro scale activities in an earlier study, and showed better understanding of concepts. The current students' answers were mostly in response to some obvious societal/environmental issues. They demonstrated having built mental models of the chemical events through the use of appropriate scientific discourse and reasoning patterns. For example a student could explain the mechanism for formation of an ester from an alkanoic acid and an alkanol and go on to tell which parts of these reactants that water and the ester would be produced from. They named and represented their structural products correctly. They were able to discuss these based on expected basic concepts and used linkage words like ‘because’ and ‘therefore’ in their analyses of situations. They explained and applied terms like polarity, electronegativity and such others appropriately. The peer verbalisation through oral, written and graphical (structural) language expressed what ideas they had in mind and their levels of understanding. The MCE activities provided enough room for these expressions.

In the post-intervention interview session, students’ impressions about their chemistry teachers and organic chemistry in general changed from a negative stand to being more positive. Their changed attitude and interest was apparent in their post-intervention test scores. It could be deduced from interview data that CBL asks for complex thinking and has the potential to encourage students to give structured explanations through higher order thinking. This is because it has the inherent ability not to ask for a single correct answer but several conceivable reasons from which a best option could be chosen through discussions. In effect a lot more than the ‘straight jacket’ prototype answer is required in the created ‘free’ but responsible environment; and this augers well for the development of higher learning skills.

The MCE activities proved to be very engaging for students. They had very positive impressions about its use. A few did not show much interest towards its use, though they engaged with it nonetheless. They intimated that the pieces of equipment were too tiny for proper laboratory work. It was clear that some students needed time to get used to the equipment. Such negative opinions were observed by Tortosa(2012) when he introduced microcomputer based laboratories in secondary schools. Majority of students in this current study intimated that the activities enabled them to visualise desired or expected phenomena. They said that the micro activities were safe to practice or use for investigations. It was user friendly and they could work without teacher-guidance. When using the MCE, concentration is more on focal scientific concepts than the tools to obtain data. With the traditional glassware, students tend to concentrate more on not breaking glassware added to the fear of sudden explosions or fire outbreaks from adding one chemical to the other, as Mafumiko(2008) and Kombo (2006) found from students in similar studies.

Teachers who were engaged in preparing the MCE activities said that they observed that using the MCE saved them a lot of work (preparatory) time as compared to the traditional activities where a lot of glassware had to be prepared for use and large volumes of solutions had to be prepared. They further added that the traditional cook book recipes could be avoided or minimised so that personal initiative from both students and teachers could be encouraged. The teachers were again, enthused about the CBL approach which they said acted as a motivating factor for students as it used real world problems to encourage transfer of knowledge and skills. By the end of the study, teacher no longer aw teaching of students as drudgery but enjoyed it. They also said that they had observed a higher attendance to class by students as evidenced in their class registers or roll call numbers. It was obvious that the teachers did what they wrote about themselves and whatever negative reports that students gave about them before the introduction of the CBL approach and MCE activities because of unavailability of resources, no in-service training, and a silent compelling force to complete an expansive syllabus within limited work schedule. Clearly, the teachers needed support with more innovative and engaging teaching approaches.

There is no single effective way of teaching organic chemistry topics. However, the results of this study and that of other studies (Bilgin, Yurukel, & Yigit, 2017; Fechner, 2009; Bennett, Hogarth, & Lubben, 2003; Stolk, Bulte, De Jong, & Pilot, 2012) suggest that CBL enhances students' understanding about many organic chemistry concepts. The use of micro equipment for activities further enhanced their conceptual understanding. This result is consistent with results presented by Tantayanon (2016), Hanson (2014), and Mafumiko (2008). After the intervention, students' understanding of many basic organic chemistry concepts improved, as observed from their post-intervention performances. About 90 out of the sample scored 47.83 as against 86 who scored about 29.67 in the pre-test. About 91.67 gained interest while 8.33 did not. Another 51.67% now attended class regularly and 38.33% not attended practical classes regularly. An average of 47.83% performed well as against 29.67 in the pre-test.

CONCLUSION

Based on obtained results, it can be concluded that CBL caused significantly better understanding of many organic chemistry concepts than when it was taught traditionally (Bilgin & Geban, 2006). The consolidation of knowledge on the topics treated was made possible by the CBL approach which used contexts from students' own background and MCE activities for 'real imagery' support so that not only were positive effects on reproduction of knowledge observed but attainment of statistically significant better results for application of concepts and favourable attitudes. The students' observed interest supported the findings of Bilgin, Yurukel and Yigit (2017) and Fechner (2009).

According to Broman and Parchmann (2014) the design principles of CBL are helpful in assessing students' application of content knowledge as well as emphasise authentic relevant topics to engage students problem solving. The study adds on to world-wide discussions on the importance of hands-on and other interactive activities as they motivate students' interest and enhance conception. It further emphasises the usefulness of integrating students' experiences that come from their interactions with their environments into inorganic chemistry lessons so that the gap between theory and practice can be bridged. It was found that active learning environments motivate students and increase their interests so that they are able to construct knowledge coherently. It could therefore be concluded that the use of CBL and MCE could affect the formation of mental models and have proved to be appropriate for the understanding of organic chemistry concepts.

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Appendix A1: Examples of pre-context based learning assessment

1. Two drinking glasses labelled as A and B which contain 0.01M organic samples with pH values of 2 and 5 respectively are said to be the same in acid strength. One is orange juice and the other B, is another alkanoic acid. What do you think? Which is best for your body? Why?
2. Afua picked up two gas cylinders labelled X and Y for her friends from a gas filling station and was told that both had two carbon atoms in their chemical structure but different in their degree of saturation and unsaturation. The one with the ‘saturation’ was to be returned as the cylinder was filled with a wrong compound. The station attendant didn’t know how to distinguish between the two so someone helped out by giving her bromine solution to use for the distinction.
   a. If gas X is saturated and gas Y unsaturated, name the two gases in the cylinder.
   b. If some amount of gas from both bottles is bubbled separately through solutions of bromine, what would be the outcome?
   c. Write the equation for each reaction.
   d. Would it affect the pH of any of our human systems or organs in any way?
   e. What effect could these gases have on the environment?

Appendix A2: Example of a context-based problem

3. Chef Lena has to prepare food flavours (pineapple, banana, and citrus) for different batches of cake that are required for a party. Cook Ama said that a mix of alcohol and an organic acid like ethanoic acid could serve the same purpose. Would this work out? Yes/No? What product would form? *(Pre-exercise/Discussion session)*
   a. Give two examples (specific names) of alcohols and carboxylic acids.
   b. What could make the mixture suggested smell good?
   c. Write the general equation for ethanol and ethanoic acid and see if they will confirm your predicted product.
   d. Write the structural formula for ethanol and ethanoic acid. Write the product and its structure and comment whether it would be any of the flavours (essences) that Chef Lena needs.
   e. What are the general and IUPAC names of the reactants and products in your balanced equation?
   f. Did Ama tell Chef Lena to add a few drops of Conc. H_2SO_4 and provide heat for the reaction? Yes/No?

i) Would those named reagents in f be necessary? Yes/No? Explain.
ii) Assuming we take too much of a reactant and have to dispose of it, what would be the effect of the disposed chemical on the environment?
iii) What would be the effect of the excess chemicals in our bodies if we eat the cake?

Appendix B: MCE Practical Activity

f. Carry out the micro chemistry activity using your micro equipment. Ensure you dispose of waste chemicals wisely as they could affect the environment and everyone else in the long run. Take minimal amounts! Why would indiscriminate or unwise disposal of the chemicals that you are expected to use 'affect everyone'?
g. Remember to provide heat/warmth for the reaction by immersing the hot end of a glass rod into the reaction mixture.
   i) Could the desired product be formed without heat? Try it.
   ii) Could the desired product be formed without Conc. H_2SO_4? Try it.
   iii) Now ensure the necessary conditions (heat and H_2SO_4) are provided. What happens?
   iv) Name the expected organic product and draw its structure.
   v) What environmental hazards could result from wrong handling of the reaction process?
   vi) How could we mitigate the problem?

Extension question

h. Obtain the containers of some food products and cosmetics and identify the names of alkanols, alkanoic acids, and alkyl alkanoates.

Appendix C: Semi-structured interview schedule

1. How have you enjoyed your chemistry class these days?
2. What could be the cause of the change?
3. Do you understand what the teacher teachers? How? Why?
4. How is your attendance to class like?
5. Do you engage in practical activities to support the principles that you learn?
6. How are the two (theory/ principles and practical work) connected?
7. Does your teacher alone do the activities through demonstrations?
8. Do you like your teacher? Why?
9. Do you expect to perform better or worse in chemistry exercises now? Why?
10. What were the main problems that were hindering your attitude to chemistry