# Enhancing Concept Understanding through the use of Micro Chemistry Equipment and Collaborative Activities

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**ABSTRACT**
This paper reports on the views of teacher-trainees who participated in a summative evaluation phase of a micro-scale chemistry collaborative instruction scenario via developed exemplary curriculum materials (the MCE approach) to enhance concept-based practical work in the University of Education, Winneba. The evaluation involved field testing of the materials to investigate the effectiveness of the MCE approach fused with collaboration compared to individual "traditional" cook-book activities on the learning of chemistry concepts by Level 200 teacher-trainees in an introductory analytical chemistry class. A total of 40 chemistry students participated in the study. The same teacher taught the inorganic chemistry topics accompanied by collaborative micro-scale practical activities to an experimental group of chemistry students (N=10) and taught the same content topic using only the MCE teaching approaches to a control group made up of biology and integrated science students (N=30). The research design made use of triangulation procedures, involving student achievement test, observation of the use of MCE approach in context by students, interviews and questionnaires. During the 10-week intervention, students carried out 10 collaborative MCE-based practical activities. The results of the study indicated that teacher trainees' reactions to the MCE approach were vastly positive. They reported that their collaboration in the MCE study was a professionally developing experience. Besides the affective outcomes, students exposed to the collaborative approach appeared to develop better scientific reasoning skills towards misconcepts discovered by engaging in small group discussions and reflections during micro-scale hands-on/minds-on practical activities than their colleagues in the control group. This paper concludes that the MCE-collaborative approach developed in this study with exemplary lesson materials, which contained adequate procedural specifications, were feasible for use in the University of Education, Winneba, and were effective in providing positive learning experiences for teacher-trainees.
**Keywords** : *Collaboration, curriculum materials, development research, Micro chemistry experiment, practical work,*

## 1. Introduction

A concept is a mental abstraction that allows generalizations and the extension of knowledge from some known ideas, objects or situations to other unknown. Concepts can be thought of as information about objects, events and processes that allow us to differentiate various things or classes, know relationship between objects and generate ideas about events, things and processes (Arends, 1990). Hence concepts must be formed properly at one's initial stage of learning. If concepts are not properly developed knowledge remains vague and inadequate to cope with later problematic situations. There is a need for teachers to explore interactive teaching methods and models besides traditional methods for clarification of concepts. Some interactive teaching methods are the use of concept-based teaching, concept maps and the inquiry approach. In concept based teaching, opportunities are provided for students to explore new ideas by making connections so as to see relationships between different types of information. Concept maps enable students to build conceptual frameworks.

Traditional classroom and laboratory based studies have revealed a mismatch between intentions (goals, behaviour, learning outcomes) and the realities, which limit the effectiveness of practical work (Mafumiko, 2006). In cases of mismatch between set and attained goals, students' understanding and outcomes tends to differ from the teacher's intentions and this limits understanding of concepts; even resulting in the formation of alternative concepts. If this occurs during laboratory practical activities, students merely follow instructions as if from a cook-book, and manipulate equipment and other resources without proper understanding. In as much as discussions and reflection on practical work is important, past research has shown that this is hardly done and as such negatively affects the intentions for which practical works are conducted (Antwi, Hanson, Sam, Savelsbergh, & Eijkelhof, 2011).

Chemistry laboratory learning enhances the understanding of theory lessons and shows how chemistry is connected with daily life (Lunetta, Hofstein, & Clough, 2007). Practical work is paramount in chemistry education because working with concrete materials helps students to understand the knowledge about their natural world. Hofstein and Lunetta (2004) intimate in their review study that laboratory activities enrich the formation of scientific concepts by fostering inquiry, intellectual development, problem-solving skills and manipulative skills. According to Neumann and Welzel (2007) in Ding and Harskamp (2011) laboratory learning is the most important bridge between theory and practice. Through this bridging, students gain better comprehension of chemical definitions and their derived equations. Laboratory work is again, an active learning method which requires students to observe, manipulate objects so as to be able to form scientific concepts and develop positive attitudes (Hofstein, Shore, & Kipnis, 2004). Creating opportunities for students to engage in appropriate experiments in chemistry laboratories increases their cognitive abilities. When this happens they are able to conceive problems and scientific questions, formulate hypotheses, design experiments, gather and analyse data and draw conclusions about scientific phenomena (Hofstein & Walberg, 1995). Lemke (2007) suggests that if students gain deep conception through practical work, they would invariably gain knowledge for transfer. This is all what education is about. Regardless these laudable purposes for which laboratory work should be conducted, the converse occurs in practice due to reasons such as lack of funds, laboratory resources, safety, time spent on preparation and execution of activities and students' time at tasks. There are a few controversial views on the importance of practical activities and how they singularly or jointly facilitate concept understanding (Herrington & Nakhleh, 2003).

Herrington and Nakhleh discuss in their paper, how independent work by students take up too much of students' study time, thus making practical work unattractive. The solitary attitude does not enable them to work confidently nor are they confident about their outcomes. Often, they merely follow hints given by their teacher so that their product could be likened to the result of a recipe from a cook-book. These observations have been made in traditional individual laboratory practice by others. Johnstone and Wham (1982) point out the issue of overload and the reduction of deep understanding in 'cook-book' laboratory learning. Lack of preparation for practical work makes it difficult for students to connect their practical experiences with the chemistry knowledge from theory lessons and so fail to comprehend what the entire exercise is all about (Shah, 2004). Thus, students must be encouraged to work collaboratively in pairs or groups to reflect about their laboratory work and to understand the theories behind them through interaction with their colleagues. Collaborative learning is strongly recommended in chemical education (McLaren, Rummel, Pinkwart, Tsovaltzi, Harrer, & Scheuer, 2008; Arrington, Hill, Radfar, Whisnant, & Bass, 2008). The collaborative approach develops powers of observation, measurement, prediction, interpretation and design of experiments. Saleh, Lazonder & De Jong (2006) advocate against the collaborative approach because they are of the view that labour is not shared equitably. They assert that less burdened students are not likely to benefit from the collaboration. Nevertheless, teacher-trainees have to learn collaborative skills, in order to apply them in their own classrooms.

Collaborative learning is a situation in which two or more people attempt to learn something together. Unlike individual learning, people engaged in collaborative learning capitalize on one another's resources and skills. They ask one another for information, evaluate one another's ideas, and monitor one another's work. More specifically, collaborative learning is based on the model that knowledge can be created within a population where members actively interact by sharing experiences and take on asymmetry roles. The theory of collaborative learning is based on the idea that learners influence one another when they learn together. They listen to each other, negotiate on the different perspectives and arrive at a mutual understanding (Miyake, 2006). Wells and Merja-Arauz (2006) confirmed in a study that learning is at its best when students engage actively in dialogic construction of meanings that are significant for them. Talking to colleagues during practical work helps students to use science knowledge instead of everyday talk (Sutton, 1998). Through this students feel motivated; they get opportunity to develop and retain scientific information.

Teacher-trainees are particularly expected to learn how to deduce and interpret empirical findings and design chemistry experiments through their involvement in practical work (Reid & Shah, 2007). Thus, the 'cook-book' methods which impose a low requirement on students' cognitive involvement must shift and give way to collaborative and more inquiry approaches. Empirical studies have shown that there is virtually no deep understanding during expository laboratory activities (Tobin & Gallagher, 1987) but rather through activities which require students to design, re-design and find new ways of solving problems, which could be through collaboration.

In recent times, facilities such as classrooms, laboratories, desks reading materials and equipment are insufficient and expensive when available. Carrying capacity, which is defined as the maximum number of students that an institution can sustain for qualitative education, based on available human and materials resources have been exceeded severally, besides the ever escalating cost of education.

There is a rapidly increasing number of students in higher institutions in Ghana, and the trend is now approaching what is common in mass education systems elsewhere - massification. As a result of large student numbers, the space requirements of classrooms, lecture theatres; laboratories and workshops are hardly met in over 70% of tertiary institutions in Nigeria (Okebukola, 2000). Facilities are overstretched thus presenting a recipe for rapid decay in the face of dwindling funds for maintenance. In these days of increased costs and large classes, institutions of higher learning have found it increasingly difficult to cope with large classes and at the same time maintain quality. The problem now is to create a balance between increasing student numbers, high cost of science based-education due to rising cost of equipment and chemicals and concept-based quality education. The adoption and perhaps adaption of micro chemistry equipment (MCE) and experimentation could be a solution to the increasing cost and lack of teaching space for increasing scores of tertiary students. Beyond the safety, economic, and environmental advantages, micro-scale chemistry offers, a number of pedagogical advantages including the following:

- engagement of students in hands-on learning experiences and provision of more opportunities for collaborative learning;
- gain in confidence to work with small amounts of materials;
- much faster to carry out, allowing students to accomplish much more in the laboratory;
- creation of enjoyment because the dullness usually associated with laboratory work is reduced since students are not merely sitting around and waiting for something to happen;
- instilling the ethics of resource conservation in students

During collaborative execution of MCE experimentation tasks, each individual depends on and is accountable to their colleague. Collaborative learning is illustrated when groups of students work together to search for understanding, meaning, or solutions or to create an artifact or product of their learning. Collaboration without explicit guidance may not yield positive results. Students will not know how to set goals and choose the best strategies for the achievement of the goals (Copeland & Hughes, 2002). This could happen in a laboratory where the teacher fails to oversee what the various groups do. Collaborative learning is closely related to cooperative learning so that with little intervention from the teacher, outcomes could still be achieved. However, in collaborative work, each team member has a contributory role to play for the success of the entire group. Vygotsky's theories stress the fundamental role of social interaction (collaboration) in the development of cognition. Collaborative learning is based on constructivism whereby the acquisition of knowledge is a social construct (Miyake, 2006). The use of miniature and inexpensive robust equipment such as Micro Chemistry Equipment (MCE) could be a good collaborative tool to use for concept formation and reinforcement in chemistry teaching and learning.

### 1.1 Statement of the problem

Laboratory applications are complementary to chemistry instruction and a necessary part of chemistry lessons. They are crucial for making abstract concepts concrete and more understandable for students (Wellington, 2007). From the researchers' observations, laboratory applications among University of Education, Winneba (UEW) teacher trainees are almost absent. Often, trainees perform activities which are not in line with theories taught in class because of lack of laboratory equipment and resources. Teacher trainees have to work individually and very carefully to master required skills but that objective is hardly achieved. They are often too mindful of the expensive glassware and large volumes of chemicals they use which could result in breakages and explosions if care was not taken. This leads to the formation of alternative concepts among teacher trainees instead of helping to build and reinforce chemical concepts. Individual performance of activities increases cost of laboratory work and does not instill confidence in the chemistry teacher-trainees as observed in a study by Johnstone and Wham (1982).

### 1.2. Purpose

The purpose of the MCE study was to explore the possibility of using the collaborative-micro-scale chemistry approach as a means to perform practical activities in chemistry classes so as to enhance trainees' concept understanding. This was also to reduce the need for highly equipped laboratories, while providing opportunities for students to engage in a process of active learning. Specifically, the study was set up to design, develop and evaluate a collaborative micro-scale chemistry scenario with exemplary curriculum materials as the support structure that could assist trainees in learning concepts collaboratively. The micro equipment was to provide opportunity for teacher trainees to repeat activities for reinforcement of concepts, work at their own pace and at the same time access experiment results in time, change working variables without fear of explosions (due to small volumes of chemicals) and yet receive immediate feedback. The study was guided by the research questions below.

### 1.3 Research questions

- How did the MCE influence students' learning of chemistry concepts?

- How did the collaborative activities incorporated into the MCE-based activities influence students' understanding of desired concepts?
- Would there be a difference in learning outcomes between collaborative-MCE based learning and MCE-based individual learning?
- What were students' opinions about the collaborative-MCE based learning activities?

## 2. Methodology

2.1 Design of the Study

The design of the study was a "Pre-test-Post-test non-equivalent (intact class) Design". The study design consisted of two groups: namely experimental group and control group. A pre-concept test was administered to both groups before teaching. The experimental and control groups were all taught by using the MCE practical approach. However, the experimental group used concept-based collaborative practical activities in addition to the MCE approach. A post-test was administered to the groups after their exposures to the MCE-collaborative and MCE-individual activities. The chemistry teacher-trainees' practical reports were analysed and evaluated in addition to their pre- and post-test results.

2.2 Sample

A total of 40 Level 200 chemistry teacher trainees in the University of Education, Winneba, Ghana participated in the study.

2.3 Research Instruments

A pre-test was designed on the basis of Bloom's Taxonomy of Educational Objectives for measuring the knowledge, understanding and application level of chemistry teacher-trainees on selected analytical and environmental chemistry topics. This test was administered as pre-test and later as a slightly altered post-test on the experimental and control groups to evaluate the extent of their concept formation through the collaborative and traditional methods of learning. Trainees submitted lab reports and filled an opinion questionnaire after the 10-week intervention period. These were followed by a focus group interview.

2.4 Intervention

Teacher trainees in the experimental group were randomly paired. In the control group, students worked individually as done in most traditional lab work. Participants had to analyse experimental results, evaluate experiments, identify and solve potential problems and write up their reports weekly. Activities were carefully planned to avoid mismatch between theory and practice as well as intentions of the activities and goals to be achieved. All activities were held in the classroom and were synchronous with the theory studied for each week. Participants were provided with as few procedural hints as possible. They attended an hour theory class which was followed by collaborative activity work for those in the experimental group and individual work for those in the control group. Before each activity a 10-minute pre-lab was conducted. Students had to come up with ways of solving posed practical problems.

Test items were structured such that they could not be solved by mere memorisation of concepts and theories. Trainees had to apply deep understanding of chemical principles which they had gained through practice. In the individual learning, trainees were not paired. Each trainee worked individually with their MCE curriculum materials while their colleagues in the experimental group worked in pairs.

2.5 Classroom practice

The main points of each lesson were consolidated at the end of the lesson. The new lesson was linked with the previous lesson as well as with the subsequent lesson. Opportunities were also provided for trainees to apply new knowledge gained in the classroom to situations in their home and general environment.

Procedure

1. Randomised pre-test for 10 minutes
2. Lecture
3. Pre-lab and MCE activities with two foci questions
4. Observation
5. Submission of completed reports
6. Post-lab
7. Delayed post-test for all two different research conditions
8. Informal focus group meeting to obtain insight into how the MCE, collaboration and individual learning contributed to gains in concept formation

## 3. Results

Lessons were observed to find out if trainees applied the interventions in developing sound chemistry concepts. Some of the indicators for assessment were their involvement with each other (in collaboration) interpretation of practical guidelines, interaction with the MCE and application of gained concept in an extension exercise. Results from the study indicated that, collaboration through the use of MCE, which was the main ingredient of change improved the understanding and performance of trainees' reasoning abilities during practical activities. The extent to which participants were observed to be interacting with the MCE either on individual or collaborative basis and how they were scored is presented in Table 1. A positive sign (+), implied that a desired action was observed among trainees. A negative sign (-) meant that the indicator was not observed. If the teacher was not sure if trainees were exhibiting a particular activity then a joint negative and positive sign (±) was used. The sign (X) signified observations which were not applicable to a group. Below is an observation schedule which was used in the study.

**Table 1: An observation schedule for an MCE practical session**

| Trainee behaviour/Activity/ Response | Lessons (Individ) | | | | Lessons (Collab) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Trainees relate prior knowledge to the day's lesson | - | ± | - | + | ± | + | + | + |
| Trainees understand what to do and form groups to begin work | ± | + | ± | + | - | ± | + | + |
| Trainee-trainee cooperation evident through equal roles | x | x | x | x | - | ± | + | + |
| Groups interact with teacher as expected | - | - | - | + | ± | - | + | + |
| Trainees show evidence of reading with understanding | - | + | ± | + | - | ± | + | + |
| Trainees show evidence of working with apparatus and materials | + | + | ± | + | + | ± | + | + |
| Materials obtained and activities started with no fuss | - | - | - | ± | - | + | + | + |
| Trainees discuss their outcomes in small groups | x | x | x | x | ± | + | + | + |
| Trainees show evidence of working individually | - | - | ± | + | x | x | x | x |
| Trainees show evidence of interpreting practical requirements all by themselves | - | - | ± | + | x | x | x | x |
| Trainees show understanding and interest in the lab procedures and activities they are doing | + | + | ± | ± | ± | + | + | + |
| Trainees are able to discuss coherently their outcomes in class with their teacher | - | + | ± | + | - | ± | + | + |
| Trainees are able to work within the allotted time | - | - | ± | + | - | ± | + | + |
| Trainees are able to relate the activities with theory | - | - | ± | ± | + | + | + | + |
| Trainees use the required scientific terms and language with comprehension | - | ± | ± | + | + | + | + | + |
| Trainees do a recap to confirm understanding of concept | x | + | ± | + | + | + | + | + |
| Trainees relate the newly learned/ reinforced concept in other situations to demonstrate permanent learning | + | + | ± | - | - | + | + | + |

It is evident from Table 1 that, all the trainees had problems on their first encounter with the MCE approach. However as time went by they were able to use the resources effectively to enhance their understanding of chemical concepts in inorganic chemistry. A closer study of Table 1 shows that trainees in the collaborative group had more positive (+) signs indicating that they understood the procedures of the MCE approach and executed them more effectively as expected.

3.1 Some identified misconcepts

Misinterpretation of terms such as accuracy and precision

Interpretation of the meaning of some constants and their applications such as in pH and Ka

Treatment of data

Misinterpretation of solubility rules and identification of ions

Paraconceptions on principles of separation

If trainees participated fully in using the MCE then it was expected that they would show a positive gain in concept understanding through practical activities (Lemke, 2007). The mean results of trainees' practical activities are presented in Table 2.

**Table 2: Analyses of Trainees' Mean Individual and Collaborative MCE lab reports (20 points each)**

| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Collaborative | 13 | 12 | 15 | 14 | 16 | 18 | 17 | 18 | 20 | 19 |
| Individual | 11 | 12 | 10 | 10 | 11 | 13 | 11 | 10 | 12 | 13 |
| Activity | MCE acid-base tests | Quantitative analysis | Mole concept & stoichiometry | Periodicity – reaction of metals with water | solubility | Qualitative test for ions | Cation identification | Anion identification | Balancing of chemical equations | Separation techniques |

From Table 2, it is evident that trainees who collaborated in performing MCE collaborative activities performed better than their colleagues who had to individually interpret activity requirements and work by themselves.

**Table 3: Mean learning achievement**

| | Pre-test | Post-test | Delayed-post test |
|---|---|---|---|
| Collaborative | 34.20 | 59.79 | 86.66 |
| Individual | 47.00 | 55.08 | 66.00 |

From Table 3, it is observed that trainees in the control (Individual) group scored higher marks than the experimental (Collaborative) group on their pre-test. Nevertheless, the collaborative group performed better than their colleagues who worked individually, when a test was conducted at the end of the study. Both groups performed well in the post-test but the collaborative group made higher gains on the test. The above results indicate that trainees' experiences with the micro-scale chemistry lessons and collaboration were mostly positive. Criticism and negative opinions about the use of the micro equipment were rare, and came from just a few trainees in the individual work group. Given such positive results, as observed in Table 3, it can be assumed that integrating micro-scale experiments into teaching would help increase student motivation and interest in chemistry. This assumption is consistent with the views of Hofstein and Lunetta (2004) that an interactive laboratory, as a unique social setting, has (when activities are organized effectively) great potential to enhance social interactions that can contribute positively to developing attitudes and cognitive growth

All the trainees showed a significant positive change in their approach to learning after the 10-week MCE intervention. Their positive change was assessed through an opinion questionnaire as to whether they enjoyed learning with the use of the MCE. The result of the opinion survey is presented in Table 4. Attitudinal change, however, was not an issue of study in this research.

**Table 4: Trainees' likes and dislikes**

| Theme | Like % | Dislike % |
|---|---|---|
| Easily understandable materials | 78 | 28 |
| Too many things to read | 45 | 55 |
| Helps to refute wrong ideas | 87 | 13 |
| Confirms correct concepts quickly | 69 | 21 |
| Helps to build concepts from first principle | 81 | 19 |
| MCE practical work gave faster and observable feedback | 94 | 6 |
| Interactive and collaborative | 88 | 12 |
| Encourages critical thinking | 67 | 33 |
| Sharpens observational and manipulative skills | 89 | 11 |
| Builds accuracy and precision | 88 | 12 |
| More conceptual gains than in traditional lessons | 75 | 25 |
| Systematic presentation of lessons and activities | 69 | 31 |
| Longer discussion periods | 87 | 13 |
| Pre-lab enables focus and recall on topic for the day. It prepares one on what to expect in lesson | 88 | 12 |
| Cannot perform all kinds of activities for all topics | 38 | 62 |
| Stains propettes | 51 | 49 |
| Increases confidence in ability to apply knowledge | 76 | 24 |
| Can be used in all levels of education | 72 | 26 |
| Shorter achievement time for results | 83 | 17 |

Trainees were of the opinion that they were able to construct their own knowledge and found learning to be useful and memorable through the use of the MCE. How the MCE helped to improve their understanding of chemistry concepts is presented in Table 5.

**Table 5: Trainees' opinions on how the MCE and collaboration affected their conceptual understanding**

| How the MCE helped to improve Trainees' conceptual understanding | Positive responses (%) | Not sure /negative responses (%) |
|---|---|---|
| The use of MCE was very helpful in my understanding of concepts | 76 | 24 |
| The outlined practical activities and my understanding of concepts helped me to prepare better for other related topics | 78 | 22 |
| The use of MCE has given me confidence in planning other basic activities on my own | 78 | 22 |
| Cooperation in class enhanced my conceptual understanding of chemical principles | 80 | 20 |
| The use of MCE helped me to develop a better conceptual understanding about Quantitative analysis | 84 | 16 |
| The use of MCE helped me to gain a better conceptual understanding about Qualitative analysis | 85 | 15 |
| The use of MCE helped me to understand more about separation techniques | 83 | 17 |
| The use of MCE helped me to understand more about the Stoichiometry concept | 84 | 16 |
| The use of MCE helped me to have a better conceptual understanding of how to balance chemical equations | 87 | 13 |
| The use of MCE helped me to understand more about the Acid-base concepts and the solubility rules | 87 | 13 |
| The use of MCE helped me to understand more about the pH concept | 86 | 14 |
| The use of MCE helped me to have a better conceptual understanding about acid-base strengths and their different titration curves | 83 | 17 |

It is evident from Table 5 that more than 75% of respondents expressed positive opinions about the effectiveness of the intervention on their conceptual understanding. This supports Treagust, Duit and Fraser's (1996) assertion that the performance of practical activities and concept development go together. These outcomes were further triangulated for confirmation through focus group interviews with both groups.

3.2 Interview with the Collaborative and Individual groups

A general focused group interview for the entire group centred on the importance of hints in laboratory activities, collaboration, memorisation, interaction with materials, understanding of written reports, self-confidence and if any alternative concepts were discovered and corrected through the practical activities. Trainees in the collaborative group (experimental) are designated as $T_{Collab}$ while those in the individual 9conteol) group are represented as $T_{Ind}$ in their responses to interview questions.

Samples of the participants' responses to questions in the semi-structured interview were:

$T_{Collab:}$ *'The micro chemistry equipment was exciting to work with. It makes you work with precision. I understand that term better now.*

$T_{Collab}$*: In the MCE activities we reached our end points very quickly. It is not like doing proper titration where you titrate for a long time. Calculations are done by simple relation or from first principle so it is easy to understand.*

$T_{Collab}$*: Results were obtained very fast and so we were able to repeat activities and even try them out in different proportions and other combinations that we were not told to do. It was fun*

$T_{Ind}$*: The MCE helped me to know how acid rain is really formed. I produced* $SO_2$ *gas and pumped it into water, all by myself. The resulting water was acidic. Interesting. I was able to calculate the amount of dissolved* $SO_2$ *with little fuss.*

$T_{Ind}$*: I was able to learn in a short time how to form solutions accurately. It also helped me to know how wrongly I understood the terms strong and concentrated solutions and corrected myself. Now I know exactly what the terms means; I mean, I understand the differences between them.*

$T_{Ind}$*: It is so difficult to work all by yourself and not be able to find out things which bother your mind. When you work with a colleague you have a good discussion and arrive at a consensus on what to do so you make little mistakes. No, it doesn't make me feel like I will make mistakes when I work on my own because I am learning all the petty petty basics that I need as a springboard now. Thanks to MCE.*

The statements above were gathered from both the Collaborative and Individual research sample. Though the responses are mixed, it is easy to decipher and know that the indicial group did not fare as well in their MCE activities as the Collaborative group. None the less, they all thought the MCE activities were interactive and facilitated their understanding and formation of chemistry concepts. The collaborative/experimental group was also interviewed. The question asked was 'How did the collaborative MCE influence your understanding of analytical and environmental chemistry concepts?' some of their responses are given below.

3.3 Results from focus group interview with trainees in the Collaborative group

$T_{Collab}$*1: Working with colleagues was quite interesting. A few are slow or too quiet …. Not sociable …. But it was still okay working with them. We were help to each other.*

$T_{Collab}$ *2: A few of my colleagues and I argued a lot but we always managed to reach a consensus and our work came out well. Yes…. We understood the concepts well at the end of our arguments … no… discussions*

*Some members were not nice to work with. They were too authoritative. Sometimes, in the end they were wrong and you were right instead with interpretation of data*

$T_{Colla}$*b3: You got a lot of encouragement from your colleagues when understanding instructions and design of activities became difficult for you to proceed*

$T_{Collab}$*4: Sometimes I reflect on my arguments and discussions after class and I come to appreciate my colleague's line of reasoning. I do a self-analysis and come to understand the chemistry topic better*

$T_{Collab}$*5: It's fun to work in pairs. It lessens the burden of interpreting what to do and understanding your outcome. I corrected a lot of my wrong ideas through help from my colleague.*

*Collaborating with our peers makes us more responsible. You are a stakeholder in making the activity a success and so it forces you to put in your best. Besides, you don't want your group to be the one with the least mark so you work hard. You clean up together too (laugh).*

The above responses indicate that trainees had positive interactive experiences through collaboration. They jointly felt responsible for the successful outcome of the MCE activities amidst the fun of collaboration.

3.4 Focus group interview with the Individual group

Trainees in the Individual group mainly talked about the enormous benefits of the MCE as has already been discussed above. There were mixed feelings about working individually during chemistry practical work. A few had misgivings about working individually. The question was on how the MCE individual activities had influenced their learning and understanding of analytical and environmental chemistry concepts. They said that it was not easy to interpret data and do calculations by yourself. One of the comments was:

*$T_{Ind}$ 1: It's so difficult when you have new equipment and you work alone without help. You only follow hints. The little equipment was helpful this time though; if not … like it would take me a long time to work with the big glassware. Half the time I did not know what to do with data gathered.*

The above statement summarises a few of the trainees' misgivings. One of the positive statements was:

*You see, because I worked alone to interpret the guidelines and worked to achieve a good conclusion, now I understand the concepts of pH and concentration very well. Working with the MCE is good. If we all have our own kits it will be good.*

**4. Discussion**

The findings from the results indicate that during collaboration, some trainees do not give of their best. A few also monopolised all the activities to the detriment of their colleagues. Like Saleh, Lazonder and De Jong (2006) advocate, labour must be shared equally or else the purpose for collaboration will be defeated. Nevertheless, there were more positive statements about collaboration than negative statements confirming what Miyake (2006) said about collaboration enabling students to arrive at mutual conclusions and understanding. Wells and Merja-Arauz's (2006) findings also supports the outcome of this study on collaboration that learning is at its best when students engage positively in dialogic construction of concepts that are significant for them.

From Table 1, it is evident that through collaboration, the experimental group was able to adapt quicker to the use of the MCE during practical sessions than their counterparts in the control class. The collaborative class had more pluses as compared to the Individual group for the set parameters of observation. The control class which did not work collaboratively spent so much time raising their hands for help from their teacher. There was always a lot of fuss at the start of each activity for the control group as shown in their first four lessons. This implies that they were going to have less work time in which to build sound chemistry concepts. The control group trainees relied so religiously on the few hints given by the teacher as if they needed them to be successful in their final practical outcomes. The large number of the control group made it difficult for the teacher to provide adequate help for all of them.

The Micro-scale practical activities were very helpful in engaging all the trainees actively in the learning process, and stimulating their interest in chemistry lessons, even though the collaborative group used more scientific terms correctly and formed more grounded chemistry concepts (as evidenced in a delayed post-test in Table 1). The usefulness of the MCE in this study supports similar positive findings made by Mafumiko (2006) and Arrington et al. (2008). Again, the findings of this study strongly suggest that the use of micro-scale experiments in chemistry teaching have the potential to promote an active classroom learning environment through small group activities (Ding & Harskamp, 2011; Reid & Shah, 2007). The obtained results from practical activities support previous work in micro-scale chemistry (Bradley, 2000; Trowse, 1998; Vermaak, 1997) and seem to be consistent with other research which shows that students 'participation in practical activities leads not only to greater understanding but also to greater interest in the study of chemistry (Demircioglu, Ayas, & Demircioglu, 2005).

Interest levels of participants in the study and understanding of chemistry concepts increased greatly especially through collaboration. For example, trainees in the experimental group indicated that they enjoyed chemistry lessons with micro-scale practical activities because it made them actively participate in the lesson, it helped them understand more about the solubility and precipitation topic, gained confidence to carry out experiments by themselves, and liked discussing experimental results in small groups as it increased their cooperation and sharing of ideas. This finding is in line with that made by Antwi et al. (2011). All the trainees became aware of the opportunities of using an entirely new approach to conduct practical work with minimum resources so as to enhance learning. Trainees were excited with the micro experiment experiences and said that it was easy, more interactive and enjoyable, allowing them to carry out experiments by themselves, learn to collaborate with peers, and communicate with their teacher freely.

Trainees in the collaborative group expressed the same positive comments as their control group colleagues. They in addition showed a higher self-perception in developing problem-solving skills than their counterparts in the control group as indicated in other research. This positive outcome through the process of collaboration was reported in a collaborative study by Ding and Harskamp (2011). Their gross averages on their post tests and practical sessions were higher. They also showed better performance in a delayed post-test as compared to their non-collaborative colleagues even though they all used the MCE. This show of high performance as against the control group could be attributed to the collaborative practices, an additional intervention, for the experimental group. Thus, the collaboration among the experimental trainees must have been the cause for the difference in performance.

 

## 5. Conclusions drawn from findings

The findings from the study were that collaborative and MCE activities help students to support each other in the formation of sound scientific concepts. As Copeland and Hughes (2002) suggested, guidance must be an important factor to ensure students play equal roles during activities. There was a significant difference in learning outcomes between the two groups. An open and interactive class equips learners with the much needed experience with their environment which translates into the formation and transfer of concept-based knowledge. There is therefore the need to create interactive learning experiences to facilitate the formation of concepts. There is always less work to be done in MCE-concept based activities but the level of understanding is always high for learners and even higher when they are allowed to collaborate as evidenced by learning and conceptual gains in this study.

## 6. Recommendation

In view of the conclusions made above, it is recommended that teacher trainees should be given appropriate training in effective collaboration to erode the 'free-rider' idea during practical lessons. It is also expedient that trainees are given adequate instructional assistance during laboratory work since this given them the opportunity to enrich the formation of scientific concepts as well as to gain deep conception which invariably aids them to transfer knowledge when ever appropriate as indicated by Hofstein and Lunetta (2004) and Lemke(2007). It is further recommended that during laboratory activities, teachers should watch out for alternative concepts in pre-test so as to design appropriate practical work along that line. Teachers should also look out for new alternative conceptions during collaborative discussions so as to be able to design activities which will expose the erroneous concepts and help with the formation of sounder concepts through collaborative activities.

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