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The ICM Approach as a Way for Improving Leaning Science Subjects in High Schools in Tanzania

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Abstract

This paper focuses on the design and trial of the Integrated Chemistry Modules (ICM). The objective was to design the approach, thereafter try it out. Observations show that teachers and students appreciated the approach. A very significant improvement in performance in post-test in the first trial group (t (37) = 21, $p < 0.001$) was observed. Similarly A very significant improvement in performance in post-test in the second trial group (t (26) = 33, $p < 0.001$) was observed. It is concluded that video materials, classroom experiments and worksheets can assist students attain required competencies.

Keywords

Competence; Experiment; Module; Video; Materials; Worksheets; ICM; High school.

Academic discipline

The academic discipline is Education.

SUBJECT CLASSIFICATION

Subject of classification is Chemistry.

APPROACH

This is a developmental research study that involved quasi-experimental design using pre-test and post-test to assess the students' cognitive gain before and after learning through the ICM approach.

1.0 INTRODUCTION

Various studies have shown that science in general and chemistry education in particular is facing decline in enrolment worldwide [1]; [2]**.** In Tanzania, a number of publications [3] show that talk-and-chalk; as opposed to learner-centered/active learning approach dominates science teaching and learning. Teachers teach science theoretically without helping the students to develop cognitive, psychomotor and affective competencies. The main reason is the presence of curricula that are overloaded with content, leading to a teacher-centered approach [4]. A shift of paradigm from content based (teacher centered) approach to competence based (learner centered) approach is also a serious challenge even in the situation where laboratory supplies such as chemicals and apparatus is adequate. O-Saki, [5] argues that science teaching can be effective through a nurturing approach to scientific inquiry relevant for learners' context.

1.1 Context and rationale for the study

In Tanzania, competence based curriculum implementation in sciences at 'A' level is relatively weak since its introduction in 2010. Although the curriculum describes clearly the use of student-centered teaching approach as a means of implementing the competence based curriculum, it is not the case in the teaching and learning as teachers face multitude of challenges such as lack of supporting materials and lack of guide for implementation. As a result, chemistry teaching is more based on content coverage than competency acquisition [6]. The preliminary investigation revealed that chalk and talk dominate the teaching and learning in A-level chemistry where the process denies students the opportunity to experience learning through developing competencies, especially psychomotor and affective competencies. Table 1 shows the enrolment in secondary education between 2004 and 2009.

Table1: Enrolment in secondary 2004 - 2009

Level	2004	2009	% increase
'O'-Level	432,599	1,466,402	249
'A' Level	31,001	64,843	109

While student enrolment in secondary schools has been increasing, it faces serious challenges, particularly in rural schools, regarding quality education provision, especially in science and mathematics. Such challenges include large class size [7], high student-teacher ratio, inadequate books and supplies, laboratory materials and apparatus [7], [3] which lead to poor performance in science.

2.0 OBJECTIVES OF THE STUDY

The objectives of the experiment were to:

- Design an exemplary ICM approach that used the educative video materials, for both classroom and laboratory experiments and worksheets to enhance classroom competencies.
- Test the approach in the selected groups of teachers and students to assess its practicality in achieving classroom competencies.
- To assess students cognitive gain in the trial groups before and after learning through ICM.

3.0 THE EXPERIMENT

The study adopted a developmental research approach using a single group pre-/post-test quasi-experimental design. It involved the First Trial Group (FTG) called Msalato High school and the Second Trial Group (STG) called Kisimri High school. There were 74 Form Five students (average of 19 years old) from the two trial schools (47 from the FTG and 27 from the STG), two Assistant Researchers, AR_1 and R_2 respectively, who were junior university teachers and four subject teachers, T_1, T_2, T_3 and T_4 respectively. Data was collected on the ability of the teacher to use the approach to implement competence based curriculum. Teachers' reflection on the ability of the ICM approach to address classroom competencies was noted. Students' feedback on the ICM approach and students' cognitive gain before and after learning through ICM approach was noted.

Each lesson in a module was designed to contain:

I. An introductory video material that explained real life application of the lesson content before learning (affective competencies);

II. Frontal presentation to enable the subject teacher to use a chalkboard to introduce the lesson content (cognitive competencies);

III. Classroom experiments that gave the students an opportunity to test the knowledge and skills presented by the teacher during frontal presentation (psychomotor, affective and cognitive competencies). The use of grid paper and kitchen materials/chemicals in classroom experiments was highly encouraged in this part.

IV. Worksheets that assisted the students in groups to work cooperatively and collaboratively to explore further the content learned in relation to the lesson objective(s) followed by presentation and discussion of the findings. This enabled the students to develop both cognitive and affective competencies.

V. Summary and conclusion which enabled the teacher to summarize the lesson basing on the specific competencies and lesson's specific objectives in relation to the observations made during the teaching and learning process.

VI. An application activity (Homework task) that strengthened the affective competencies.

The classroom teaching and learning was followed by the laboratory work that used conventional chemicals and apparatus to enable the students to develop inquiry minds-set. To assess the qualitative component, the study used *descriptive and analytical* methodology to describe classroom behavior of both teachers and students using ethnographic approaches. The values the teachers attached to the ICM approach in relation to their traditional approach, their consciousness in implementing the materials in the classroom and strands of change in the implementation process were studied.

3.1 Instruments for data collection

Non-participant observation was used to check for the attainment of lesson competencies in relation to the use of video materials, animations, experiments and worksheets. The ability of the teacher to adapt the ICM approach was observed during the process. Unstructured in-depth interview protocols were used to get straightforward factual information and insights into teachers' and students' opinions, feelings, emotions and experiences in the ICM phenomena. The in-depth interview protocols were used to obtain unique information or interpretations held by the teachers and students in the aspects which the researcher was unable to observe during the classroom implementation process. Students' overall lesson evaluation sheets were used after every lesson to evaluate the attainment of the lesson competencies. Both the pre-test and post-test were used to assess the students' cognitive gain before and after learning. The pre-test was used to determine if students initially had any major variations on their understanding of the content in the module before learning through the ICM approach. The post-test was used to assess the students' gain after learning.

3.2 The ICM procedure

The implementation of the ICM approach followed four stages: orientation, pre-tests, classroom implementation, and post-tests. The teachers were provided with hard copies of the lessons materials for self orientation to the ICM approach. Video material observations, preparation and testing of the experiments was letter introduce. Reflective meetings helped the teachers to acquire some of the preparation knowledge and the use of alternative materials such as grid papers in plastic sheets which were often used, instead of the test tubes or beaker. A rehearsal of the lessons outside the classroom settings by the teachers under the guidance of the researcher followed. This was done until the participant teachers were well oriented to the ICM approach. Thereafter, the students sat for the pre-test, followed by classroom implementation where lesson one was conducted by the researcher while the other lessons were conducted by the teachers.

3.3 Data analysis

The *t*-tests were performed to determine any significant differences in the mean scores of pre-and post-test within and between the two trial groups. The responses from the interviews and reflective meetings were analyzed in relation to their content. The researcher recorded the information from the respondents according to the intensity with which certain words or terminologies seemed to be unique and important. The information obtained through this approach was organized in quotations and inferred within the context of the study. Analysis was done with regard to the category, relationship of words and concepts in relation to the research objectives and questions.

4.0 THE FINDINGS

4.1 The ICM approach

Ten modules were designed following the suggested guideline. However, in this paper we report on the findings of module number 8 (chemical kinetics) that contained six lessons namely; Introduction to the rate of chemical reactions, Factors affecting the rate of chemical reactions (concentration), Factors affecting the rate of chemical reaction (temperature), Factors affecting the rate of chemical reaction (catalysts), Reaction mechanisms and rate determining steps and first and second orders of chemical reactions. Table 2 shows a transcript of Lesson 1 in this module.

Table2: An exemplary lesson: Comparing reaction rates

Introduction (10 minutes): The teacher is advised to Introduce the lesson through minds-on activity that require the students to explain briefly meaning of the term 'chemical kinetics' and list daily activities that can be used to describe the concepts in the rate of chemical reactions. The teacher allows the students to observe the lesson video materials which provide the students with real life application of the rate concepts.
Frontal presentation (15 minutes): The teacher delivers the lesson content through discussion using examples including: **Slow reactions** *e.g.* Rusting of iron (nail), decomposition of H_2O_2 in air, ripening of fruits/banana, fermentation of flour by $NaHCO_3$, and oxidation of alcohol (wine)*; and* **Fast reactions** *e.g.* Decomposition of H_2O_2 in the presence of a catalyst (KI or MnO_2), reaction of metal with acids [e.g. Zn(s) + $HCl_{(aq)}$] and Combustion of $CH_{4(g)}$.
Experiments (20 minutes): The students in groups predict the outcomes of the reaction of magnesium ribbon and lemon juice, and magnesium ribbon and acetic acid.
Worksheet (15 minutes): The students attempt the worksheet cooperatively and collaboratively e.g.: a) Fresh milk left in air turned sour after sometimes but that put in a fridge (Below +4 ^{o}C) did not. b) A cup/bowl made of iron rusted when washed and left in air for hours but that made of aluminum cup/bowl did not.
Discussion, question and answers (15 minutes): Students to present and discuss the worksheet
Summary and closure (5 minutes): The teacher concludes the worked out lesson objectives and emphasizing on the application of the fast and slow rate concepts in the real life.
Homework/Application activity: The teacher is advised to stimulate students' further reading by providing students with the handouts containing homework.

The findings from classroom try-out in the FTG and STG indicated that the students' interest and motivation increased. The teachers were also interested and eager to implement the approach. They slowly changed from the traditional way of implementing the lessons from content (chalk and talk) based to competence based teaching through the use of video materials, experiments and worksheets. They seemed to have a continuous ability to adapt the approach inside the classroom.

4.2 Orientation stage

After trying the ICM approach, the teachers claimed that before the use of ICM they used to rush to fulfill the syllabus requirement but not to develop students' competencies through simple classroom and laboratory experiments, video materials and worksheets. The T_1, T_2 and T_4 said that they normally started the module directly with heavy content without building up students' interest and understanding of the concepts. T_1 and T_4 were worried of the implementation time as the ICM approach included video materials, classroom experiments and worksheets that could consume much time. In the end, they were satisfied with the time after trying the approach. T_4 said:

> *"I can see…It is necessary for students to do simple demos/experiments inside the classroom…I spent much time than expected in the traditional approach…This approach makes life easier".*

During rehearsal, T_4 extended the lesson beyond planned time because he was ambitious to stop at the exact time but, he had not mastered the ICM approach.

4.3 Classroom implementation of the ICM approach

The observations indicated that there was a reduced time of classroom implementation of the ICM approach in the STG as compared to the FTG.

4.4 Findings from teacher implementation of the ICM approach

The teacher in the two groups noted that the ICM approach developed better pedagogical content and knowledge in Chemistry. They skipped some content of the curriculum that seemed difficult, abstract or never appeared in the examinations. Teachers were recorded saying:

T_4: *"I never taught the concepts of fast and slow rate because they rarely appeared in the national examinations…"*

T_1: *"The reaction mechanism and stoichiometry concepts were difficult for the students to understand although do not appear frequently in the examinations".*

T_1: *"This approach makes life easy" meaning that, the approach is comfortable.*

Generally, the teachers and students were interested and motivated in the ICM approach as it made abstract concepts clearer and easy. They strongly suggested that the ICM approach was a means of assisting them to implement cognitive, psychomotor and affective competencies.

4.5 Findings from the students learning through the ICM approach

Observations from classroom implementation of Lesson One in the FTG showed that 10 (27.03%) out of 37 students had difficulties in observing the video materials because of English language difficulties. However, discussions after the lesson realized that the students were able to master the video content.

This was revealed in the discussion of students during video observations in FTG: The students were recorded saying:

***In lesson 2*:** "I observed in the video the collision of molecules…can elastic and inelastic concepts be related to the concepts of rate?"

***In lesson 3*:** "What is the difference between the strength and concentration as observed in the video? What makes the reaction of higher percent much faster than that of less percent?"

***In lesson 4*:** "The question below the video is not matching the content of the video".

***In lesson 6*; Group 1:** "This video is nice. I see from the video that decay process is associated with shrinking. Can we conclude that the rate of shrinking is proportional to the collision of substances in the substance?"

***Group 3*:** "…no, the strength and concentration have relation…Did you not observe in the video that the 30% worked faster that the 3%...I remember…"

In Lesson 7: "What will happen if the activation energy was lowered to zero, and what if a very small amount of catalyst was used in the reaction?"

After the lessons, the interview protocols with students revealed that they enjoyed the ICM approach. Some students were recorded explaining:

***In lesson 3*:** "Nowadays I do not sleep during the lesson…the lesson made me active all the time".

***In lesson 4*:** "I have read the books, but the concepts were not clear...the new approach has made me understand them well…The funnel demonstration on rate determining step can be done as class experiment instead of a video".

The students further explained that the videos demonstrations enabled them apply some of the learned concepts at home. One example given was the possibility of making soft drinks and bites . Although the students commented positively on the evaluation sheets based on ICM approach, they strongly recommended that the teachers had to prepare themselves before the lesson. This is because, initially, the teachers dominated more the lessons than letting students to freely interact with learning activities.

4.6 Students' reaction on the experiments

Classroom experiments were reported by the students as interesting, educative and developing critical thinking. However, some students reported the experiments to be dominated by few members of the groups as every student liked to touch the chemicals, apparatus during experiments. Two students in FTG were recorded in Lesson Three commenting as follows:

1st students: This experiment is very interesting.

2nd student: Let us repeat with different amount of the chemicals to see the results.

1st student: I see the blue colour is changing into yellow.

2nd student: Is it yellow or dark? What does it represents?

Similarly, students in the STG were recorded asking the following questions after experiments:

***In Lesson Two*:** What do the bubbles represent in the reaction of acetic acid and magnesium?

***In Lesson 7*:** What will be the activation energy if a very small amount of catalyst is used in the reaction?

Moreover, students in the STG were recorded arguing as follows:

***In Lesson Four*:** "No experiment in this lesson? I like experiments"

***In Lesson Six*:** "What was the significance of soap in this reaction? Is it a catalyst? Let us try to add different amount of it in the same amount of reagents and observe".

This showed that the experiments engaged students to critical thinking.

4.7 Students views on the worksheets

The students suggested enriching the worksheets, with examination questions. They explained that the ICM approach facilitated understanding of difficult concepts through discussion of worksheets. A student from the STG reported through evaluation sheet as follows:

"Nowadays I do not sleep in the lesson… I always talk, observe video materials and perform experiments".

The students identified a typing error in one of the chemical expression during the derivation of the 'First Order Reaction Equation' in Lesson Six showing that they actively participated in the lessons. General observations showed that some video materials, including the demonstration of slow reactions and collision theory, needed a critical revision. Also, the deriving questions below some video materials needed to be restructured for the student to understand.

4.8 Findings from learning achievement

The students in the FTG spent 40 minutes to finish the pre-test and in the STG they spent 27 minutes. Students in both groups reported the test to contain difficult items. They reported to attempt few items which were related to the concepts learned in "O" Level. However, they performed better in the post-test as compared to the pre-test. Table 3 summarizes the pre-test and post-test results in FTG and STG.

Table3: Summary results

GROUP	Pre-test mean score (%)	Post-test mean score (%)
FTG	14.05	68.01
STG	5.56	76.01

The mean scores of the pre-test in the FTG (14.05%) and STG (5.56%) indicate that the students had not mastered the module. The post-test results showed that STG scored higher (mean, 76.01%) than the FTG (mean, 68.01%). Generally, the STG performed relatively better than FTG.

The dependent sample *t*-test showed that, the mean on the pre-test in the FTG was 14.56 (sd = 5.80) and the mean on the post-test was 68.01 (sd = 15.17). A very significant increase from pre-test to post-test was found (t (37) = 21, $p < 0.001$). This implies that there was a significant difference in the mean scores between post-test and pre-test in the FTG. Similarly, in the STG the mean on the pre-test was 4.56 (sd = 4.76) and the mean on the post-test was 76.20 (sd = 11.02). A very significant increase from pre-test to post-test was found (t (26) = 33, $p < 0.001$). The independent-sample *t*-test of comparing the post-test mean scores of the FTG and STG revealed a significant difference between the means of the two groups (t (63) = 4.00, $p < 0.05$). The mean of the STG was significantly higher *(m = 76.20, sd = 11.02)* than the mean of the FTG *(m = 68.01, sd = 15.17).*

5.0 DISCUSSION

5.1 Testing of the approach

Observations in this study indicate that, initially teachers implemented the ICM approach differently because they were used to the traditional methods of talk and chalk [4] that denied learners an opportunity to develop competencies in the subject (Osborne 2007). This is prominent in rural areas that leads to learners' inability to relate science concepts to the reality; hence, unsuccessfully able to solve life the problems [2]; [4] such approach of science implementation makes the learners to perceive science as difficult because sciences hardly develop their cognitive, psychomotor and affective competencies [4].

The findings from this study describe the importance of the ICM approach in enabling teachers to engage the learners in competence development through video materials, classroom and laboratory experiments, and worksheets (VEW).

During implementation of the ICM approach, large groups of learners were observed to realize the contribution of VEW in developing scientific concepts. The video materials enable the learners to realize real life application of the concepts before they learned them.

Learning through video materials seemed to develop cognitive competence to the learners as they stimulated their mental process [10]; [11] through hypothesis generation, asking right questions, making observations, and designing ways to get solutions. Mayer & Moreno [11] contend that presentation of words and pictures are the two most common modes of presentation and are central to information processing. Integration of videos, sound and printed texts in science education has a positive impact on both teachers and students. Smith, Rafeek, Marchan and Paryag [9] found that video-clips of tooth preparation were able to replace live demonstrations in a preclinical operative dentistry course. Similarly, Chang & Yang [10] found that curriculum components-flash animations induced to the students a relatively high cognitive ability resulting in better concept achievement. Thus, video materials can create a scientific competent community among the students [12].

The experiments in the ICM approach engaged the learners to a multitude of psychomotor activities including recording data accurately, using instruments, practicing safety and cleaning apparatus. For instance, the learners were observed repeating the experiments several times using different amount of chemicals in order to develop a conclusion based on the relationship between surface area and rate of chemical reactions. Ross, Lakin & Callaghan, [13] argue that such psychomotor activities build up pictures of the world in their minds of students. It is important to realize that worksheets can as well develop competencies to the students as the video materials and experiments do.

During the worksheets sessions the students discussed the scientific concepts regarding the video materials and experiments, confronted with various challenging real life situations and suggested solutions. They also interpreted the consequences of observations made in the experiments and videos, and judge the accuracy of their predictions. Such a social learning enables the students to share ideas through interaction with colleagues, teachers or materials and develop students' competences within classes and outside the school [14].

5.2 Assessment of students' cognitive gain

The dependent sample *t*-test for pre-test in the FTG was (t (37) = 21, $p < 0.001$) and in the STG was (t (26) = 33, $p < 0.001$). The independent-sample *t*-test in FTG and STG was (t (63) = 4.00, $p < 0.05$). It implies that the ICM approach increased the students learning ability to the significant consideration as the materials continue to be improved and tested in different learning environment. O¨ Zmen, (2008) showed that well designed and tested curriculum materials motivate students and enable them to perform better in subjects.

6.0 CONCLUSION

It is concluded that in under resourced high schools, video materials, classroom experiments and worksheets (VEW) can be used to assist teachers and learners to attain the expected chemistry curriculum competencies. There was also an increased cognitive improvement among the students after learning through the ICM materials. It is recommended that the ICM approach can be improved through the use of video materials based on Tanzanian context.

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