CHEMISTRY TEACHERS’ ROLE IN CHANGING PRACTICAL WORK FROM “HANDS ON” ACTIVITIES TO “MINDS ON” ACTIVITIES

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Practical work is important in the effective learning of Chemistry. In most Kenyan secondary schools practical work mainly involves ‘hands on’ activities where learners follow laid down procedures to arrive at a predetermined outcome. This may lead to working without much thought of the actions and thus low conceptualization resulting in poor performance in chemistry at the end of the course. This study aims at providing alternative approach on how to engage the learners’ mind more in practical activities. Data was collected through observations of practical lessons, followed by analysis of instructional materials used by chemistry teachers and questionnaires for the chemistry teachers. The findings showed that the strategies used to teach practical work did not adequately focus on the learners’ ‘minds on’ the activity. The teachers, therefore, require design and resource support for the implementation of learner-centred investigative practical work in secondary school chemistry.

Keywords: Instructional Materials, “Minds On” Practical Activities, Practical Investigations

Introduction

In order for chemistry practical work to be effective in producing meaningful learning, the teachers should develop activities that engage the learners in scientific investigations in which their minds are focused on the activity and its outcome. Science educators argue that practical work should involve learner-centered learning environment that engage students in knowledge construction, as opposed to teacher-centered environment which involves information absorption (Gravoso et al 2008). Conventional methods of teaching practical work used in most Kenyan secondary schools mainly focuses on developing students’ knowledge in chemistry, rather than on developing understanding of scientific investigative procedures. The practice in practical work has been a cookbook trend where the instructions are carried out like a recipe that reduces meaningful learning. The learners therefore, do not use scientific ideas to guide their actions during the practical activity and to reflect upon the data they collect. Kim & Chin (2011) argue that this nature of recipe-based practical work is not sufficient to develop students ‘habits of mind’ because they involve simply doing but do not require thinking through doing. Effective practical activities should enable students to build a bridge between what they can see and handle (hands-on) and scientific ideas that account for their observations (brains-on).

Need to Support Investigative Practical Work

There has been continued poor performance in chemistry at the end of course examination in Kenya indicating that the learning of chemistry may not be as effective as required. Studies indicate that use of investigative approaches of science learning through practical work is a means of improving learning in chemistry (SCORE, 2007). Investigative inquiry approaches to learning the content and process of science has been central in the recent years yet the challenges to investigative teaching are still evident and the shift from traditional expository methods has been slow (Krajcik et al 2003). Hubber & Moore (2001) argue that ‘hands on’ activities in science practical work do not guarantee scientific investigation. This points to a need to support teachers in use of learner centered investigations. Motswiri (2004) argues that classroom practices in most secondary school chemistry lessons are characterized by chalk-and-talk and little practical work. In cases where practical work is implemented, it only requires students to follow instructions developed by
the teacher or from textbooks where the learners are supposed to strictly carry out the activities as per the instructions; sometimes without much interest or thought on what they are doing. Learners tend to follow the teacher’s guidance to the letter. It is therefore of paramount importance to change the teachers’ practice in order to achieve ‘minds on’ learning of practical chemistry.

Changing practical activities to ‘minds on’ type requires proper management of all stages of the activity. Practical work is usually carried out in four main stages (Twoli, 2006; Omosewo, 2006); planning, implementation/activity, discussions and conclusions. When these stages are well managed they can lead to conceptualization (Figure 1).

![Designing and Planning](image)

**Figure 1: Development of Understanding of Scientific Principles Through Practical Work**

Krajcik et al (2003) noted that research-based curriculum materials could address these challenges and provide improved tools for learning for teachers and students through development of appropriate instructional designs. Instructional materials can serve as learning materials for both students and teachers. Materials can also serve as a primary influence on how teachers should teach science (Krajcik et al 2003). Yandila et al (2003) quoted teachers as facing difficulties in implementation of learner-centered approach due to, among other factors, lack of exemplary teaching materials and inappropriate textbooks.

**Aim of the Study**

The main aim of this study was to develop insights into the characteristics of instructional strategies that would support teachers to engage learners in use of learner centered investigative practical work in the secondary school chemistry.

**Study Location and Population**

The study was carried out in Kajiado County in Kenya. The 42 public schools managed by the government were taken as the study population. From a sample of 19 schools, 42 teachers responded to a questionnaire and lesson observations were carried out in six schools. 47 teachers carried out the first appraisal of the materials and 3 experienced teachers carried out the second appraisal of the materials. The first try out of materials was done by three teachers who taught a total of twelve lessons. The second classroom use that involved evaluation of the strategies was carried out by five teachers in which a total of 30 lessons were observed.

**Conceptualization of the Study**

Considering that this study aimed at defining the characteristics of learner centred instructional strategies and how they can be developed and used, the study focused on instructional design strategy that involves designing, developing and evaluating instructional material prototypes. Such developmental research characterizes the situation with all its complexity instead of identifying a few variables to hold constant (Aksela, 2005; DBRC, 2003). The study considered the content of instructional materials for practical work and teaching strategies (including student engagement in designing practical work) as the conditions that affect understanding of concepts and acquisition of skills (learning outcome). Instructional strategies were designed in the instructional materials and developed through various stages to produce refined model of instructional materials that contain strategies for investigative practical work.
Methodology

This study employed a Design-Based Research (DBR) design. Design-Based Research is one terminology used to describe a research methodology that is used to design/develop an intervention (such as programs, teaching-learning strategies and materials, products and systems) with the aim to solve a complex educational problem and to advance knowledge about the characteristics of these interventions and the processes to design and develop them (Plomp & Nieveen 2007). Some scholars also refer to this research design as developmental research design (Wang & Hannafin, 2005; Motswiri, 2004). DBR design was appropriate because it helped create and extend knowledge about developing, enacting, and sustaining innovative learning environments (DBRC, 2003). DBR has an advantage of offering solutions to real life problems because the research is carried out in real life setting where learning is done, it has multiple dependent variables, it characterizes the situation with all its complexity and it involves different participants in the design who bring in differing expertise instead of being subjects of study. It is a flexible design for revision in which tentative initial set is revised depending on success (Krajcik et al, 2007; DBRC, 2003). DBR emphasizes the participatory role of practitioners. Teachers and students can become re-designers by collaborating with researchers (Aksela, 2005). Based on constructivism theory of teaching and learning, practical work instructional materials that support investigative learner-centred teaching strategies were developed.

A construct referring to step-by-step prescriptive procedure for creating instructional materials in a consistent and reliable fashion in order to facilitate learning is referred to as an instructional design model. The five basic phases of Instructional Design Model were used in the study (Gustafson and Branch 2002). The first stage involved assessment of the practices and needs of Chemistry practical work in schools. This was done through use of questionnaires for teachers, lesson observations and analysis of content in the books commonly used by teachers in chemistry teaching. Stage two involved design and development of Chemistry practical work instructional materials prototype. Design specifications were developed based on the outcome of stage one analysis, constructivism theories and state-of-the-art knowledge about teaching of science. From the specifications, the first prototype of the materials was developed. These were appraised by teachers. After the appraisals, the materials were refined and developed into a second prototype. The third stage was the try-out of the second prototypes with chemistry teachers in the form one classes. The feedback from these try-outs were used to refine the materials further thus development of the third prototype. The fourth stage involved evaluation of the instructional strategies. This was carried out in the classrooms as chemistry teachers used the materials to support their implementation of learner centred investigations. The evaluation was done using lesson observation, teacher logbook, teacher’s interview and student questionnaire. The feedback was used for the refinement of the materials leading to a model of instructional materials that support learner centred investigative work.

Findings

Use of Practical Work in Chemistry

All teachers indicated that they used some form of practical work in teaching chemistry. This implies that teachers attach a lot of value to the practical work in chemistry teaching. When asked about the method they used to teach chemistry practical work, the highest percentage of the teachers (64.3%) indicated that they commonly used demonstration method despite acknowledging that class experiments would produce better learning of chemistry concepts. A small percentage (21.4%) of teachers indicated that they commonly used class experiments. Project work was rarely used by the teachers (Figure 2).
Figure 2: Methods Used to Manage Instruction in School Chemistry Practical Work

Practical work involved placing learners into groups and providing them with detailed procedures to follow. Responses to questionnaire items showed that most teachers (80.9%) believed that providing learners with detailed procedures to follow leads to their engagement in learning. It is however important to note that merely placing learners in groups does not lead to practice of inquiry (Wachanga & Mwangi; 2004). Educationists argue that following strictly set procedures to arrive at a predetermined outcome is limiting and does not lead to meaningful learning in science (Hubber & Moore, 2001; Trowbridge et al, 2004; Motswiri 2004; Chiapetta & Koballa, 2010). There are some common practices observed during chemistry practical lessons in secondary school chemistry. The frequencies with which these practices are carried out depend on how the teacher organizes the learning activities. For the practical lessons observed frequencies of these practices was as shown in Figure 3.

Many teachers (71.4%) never allowed the learners to develop their own procedures, or carry out procedures that interested them. Some teachers did not even allow learners to question the procedures they were given. This indicates that the learners may not actively engage their minds during the practical activity. This method has been referred to as providing ‘hands on’ and not ‘minds on’ activities (Chiapetta & Koballa, 2010).
The study further showed that teachers did not have laboratory manuals that they could use for practical work. They used chemistry textbooks that are approved by Kenya Institute of Curriculum Development (KICD). Most of the practical activities in these materials appeared to be geared towards confirmation of facts and ideas and therefore provide detailed step-by-step experimental procedures. Most of the teachers (81.0%) indicated that the expected results of the practical activity were clearly outlined and most learners work towards getting the results indicated in the book. The books were found to emphasize mainly on manipulative skills and observation lacking emphasis of important skills of predicting/hypothesizing, creativity and imagination, as well as application of scientific facts. Such materials do not provide learners with an opportunity to develop their own procedures for practical activity or look for alternatives to procedures given and do not encourage thoughtful reflection on experience. This indicates the need for special instructional material support for practical work in chemistry teaching and learning. The lessons observed indicated that teachers used the textbook as guide for structuring their lessons. Learners were not accorded opportunities to engage in scientific arguments and support the outcome of their experiments. Similar weaknesses concerning instructional materials have been noted by other researchers (Motswiri, 2004; Krajcik et al, 2003).

Design and Development of Instructional Materials that Support Investigative practical Work

Having established the convectional materials and practices, the researcher set out to develop an initial prototype of the instructional materials that would support teachers in implementing investigative practical activities in chemistry. These were designed as a set of six lessons from the topic, *acids, bases and indicators*. This is a topic in Form One KCSE syllabus. The design specifications for the materials were informed by needs for chemistry teaching and learning of practical work as identified from stage one of study, constructivism theory of learning, and literature on by other researches (Reiser, et al 2003; Motswiri, 2004; Ottevanger, 2013, Davis et al, 2014). The design specifications included a focus on: science
content, scientific practices, scientific literacy practices, participation structures and
assessment opportunities:

The features of appropriate instructional materials were adapted. These are pedagogical
appropriateness, appropriate science content and presentation and format (National Science
Resources Center, 1997; National Academy of Sciences, 1998). A number of evaluation
processes were carried out (Nieveen, 1997; Motswiri, 2004; Ottevanger, 2013). The first was
expert appraisal in which experienced teachers appraised the materials and identified areas
that required review and improvement. The appraisal was guided by a structured
questionnaire that mainly comprised open-ended questions and an informal interview. The
results indicated that the materials reflected the KCSE syllabus and could be used in the
classroom. Suggestions were made for adjustments of materials that were to be used for
practical experiments. There was a general agreement that the materials would be
instrumental in guiding the teacher through discussions during the lesson and in helping
learners build information on their prior knowledge.

Science education lecturers from the university also appraised the materials with the
purpose of enhancing consistency of the materials and research instruments. Their views were
used to review and redesign the materials producing a second prototype. Three teachers tried
out this prototype with their students in their classrooms. This focused on the practical
usability of the materials in the chemistry classes. The results were used to review the
materials producing the third prototype. This prototype was taken for a field test where
evaluation of practicality and effectiveness were carried out. Five teachers in their classrooms
used the instructional materials for a series of six lessons. The results of the evaluation were
used to refine the materials further producing the final version. These evaluation activities in
the study were embedded in a cyclic approach of design and formative evaluation for the
development and refinement of the instructional strategies for learner centered investigative
practical work.

Evaluation of the Materials

The instructional materials consisted of the teacher guide and student materials that
composed six practical lessons covering the topic of acids, bases and indicators. The
teacher's guide provided detailed procedures on how to guide the learners through each step
of the investigative process including predicting/hypothesizing and formulation of procedures
to use for the activity. The evaluation involved use of the materials with five teachers in their
chemistry classes. This involved a total of 144 learners. A total of 30 lessons were carried out.
The evaluation of the materials was carried out to determine the instructional support the
materials provided in achieving learner centered investigative practical work. The key criteria
for this evaluation were guided by determination of practicality and effectiveness of the
materials in actual classrooms (Krajcik et al, 2003; Nieveen, 1999; Otteavenger, 2013).
Practicality was evaluated as measure of the materials' quality, which was indicated by
support, clarity, congruence, complexity, and cost as perceived by the teacher using it in the
context of his or her practice.

Lesson observation schedule was used to guide the recording of observations made
during the practical activity. The teacher was provided with a logbook to record the
happenings in each lesson carried out. This contained structured guide with open-ended
questions to guide the teacher. The teachers were interviewed at the end of the lesson series
and the learners responded to the student’s questionnaire. The Lesson observation guide was
outlined as teacher expected actions in an investigative lesson set-up were the researcher
recorded whether the expected action was observed or not. Teacher interview and logbook
provided information regarding their perception on how the materials supported them in
implementing learner centered investigative practical activities. They also provided the
researcher with teachers’ perception on the effectiveness of the materials. Lesson observations
provided data on practicality and effectiveness as observed by the researcher while questionnaire for students provided feedback from the learners. The average percentage of expected teacher actions observed during investigative practical work in each of the six chemistry practical lessons was calculated (Table 1).

**Table 1: Observed Teacher Actions During Investigative Practical Work**

<table>
<thead>
<tr>
<th>Lesson Phase</th>
<th>Lesson number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td></td>
<td>60.16</td>
<td>79.98</td>
<td>91.42</td>
<td>79.98</td>
<td>88.56</td>
<td>91.42</td>
<td>81.92</td>
</tr>
<tr>
<td>Development</td>
<td></td>
<td>71.22</td>
<td>86.30</td>
<td>86.32</td>
<td>85.04</td>
<td>78.80</td>
<td>78.80</td>
<td>81.08</td>
</tr>
<tr>
<td>Conclusion</td>
<td></td>
<td>63.36</td>
<td>74.28</td>
<td>93.32</td>
<td>84.26</td>
<td>89.98</td>
<td>76.66</td>
<td>79.75</td>
</tr>
</tbody>
</table>

From Table 1, it can be observed that an average of 81.92% of expected teacher actions were observed in the introduction phase of the lessons, 81.08% expected teacher actions were observed in the lesson development phase and 79.75% actions were observed in the conclusion stage. These high percentages were taken to be an indication that the materials were used as intended by the developer and were able to facilitate teaching of practical work.

From the logbook and the interviews, the teachers indicated that the objectives for all the lessons were achieved. This implies that the materials were effective in their classes and were able to offer support for the implementation of investigative practical work. Concerning congruence, the teachers indicated that the practice was very different from what they commonly used in class but also indicated that the investigations would be easier to carry out when supported by such materials. All the teachers indicated that they experienced a problem with learners adjusting to the practice of developing their own procedures while they were used to being provided with step-by-step procedures for all their practical activities. The teachers indicated that the method had high demand on resources but also agreed that the materials were available and all it required was change in teaching approach as well as innovativeness.

The responses from students also showed that most students (83.3%) perceived the structure of the practical activities as motivating and helpful to them in carrying out the investigations. The responses that agreed to the statement ‘doing practical work by setting our own procedures makes practical work easier and more satisfying’ were quite high (88.2%). A high percentage (90.7%) of the learners indicated that they enjoyed the activities. Students perceived the exemplary materials helpful to their learning and understanding (88.2%). They perceived that they were able to learn the concepts easily because the developing their own procedures made them think about what they were doing. These were indications that if chemistry teachers could be supported by appropriate instructional materials they can make practical work a ‘minds on’ investigative activity.

After the evaluation the materials were refined to produce a model of materials that would support teaches in implementing learner centered practical work. The materials were meant to guide the teacher in carrying out a practical activity that would engage the learners both mentally and physically. The model instructional materials can be considered as a sample lesson planning and implementation guide. The basic structure of the practical activity
resembles the common outline of a practical lesson involving planning, introduction of the lesson, lesson development and conclusion. The model guides through sequencing of instructional activities, which starts with identification of content to be taught to a particular group of learners based on their learning level. The general process of learner centered investigative practical lessons used in the study can be summarized as shown in Figure 4. It serves as conceptual framework for organizing and sequencing a set of instructional activities to build meaningful student learning.

![Figure 4: Model for Organizing and Sequencing Instructional Activities in Practical Work](image)

Planning involves designing the activity, identification of required materials and safety precautions. The teacher guide provides detailed ideas on how to introduce the activity, which could be through a simple exercise, prediction, observation, examples or discussion. The discussion is tailored to assess relevant prior knowledge, identify preconceptions or
misconceptions in science learning related to the particular activity. The teacher is guided to use open-ended driving question that would arouse learners’ interest in the activity (Krajick et al., 2007). The lesson development section is broken further into sections of planning for the activity, plenary discussion of the procedures set and the carrying out of the actual activity. Learners are grouped in small groups of 2-4 learners and allowed to brainstorm on ways of carrying out an activity to achieve the objective set. They are provided with the apparatus or list of apparatus they will be using and allowed to plan for the investigation. Learners then develop their own experimental procedures. After the discussion of the procedures in groups, the learners are called to attention for plenary discussion with the teacher. The outcome of their discussions is presented and the teacher guides through the refinement of the procedures. The learners are allowed to carry out the practical activities using the procedures they have developed. They record their findings in their notebooks as they progress with the activity. Consolidation and discussion of results is done after the learners have carried out the activity. This involves pooling together their findings by receiving feedback from groups of learners. The teacher should then guide learners to make meaning in their discussion, and make conclusions related to the focus question or prediction, evidence and connection to the real world.

**Conclusion**

Teachers have a facilitative role in the learning using practical work in chemistry. They can change the commonly used procedures of teaching practical work into investigative activities involving: planning and designing practical activities, implementing their plans, carrying out analysis and interpretation of the results and applying the knowledge they acquired as a result of taking part in investigative practical work. It was deemed important to provide the teachers with instructional materials with sufficient details that support these activities. Instructional materials used in this study were a useful guide to the teachers in organizing learning resources, preparing students for the concept of the study, guiding students during their practical work activities and assisting learners in constructing meanings of the results of the activity. Most of the teachers were able to guide learners through development of the procedures using the teacher guide provided. This provided the lesson with the much-desired characteristic of being ‘minds on’ as well as ‘hands on’ activities. During the initial lessons, teachers felt that the approach was very demanding but with time they found the activities fulfilling.

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