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Effectiveness of Hands-On Activities to Develop Chemistry Learners' Curiosity in Community Secondary Schools in Tanzania

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ABSTRACT
Learners' curiosity is among the affective domains of learning that has a great potential to take learning to higher levels and meet the demands of the 21st-century teaching and learning process. This paper assesses how hands-on activities performed using learning materials from learners' immediate environment can enhance learners' curiosity in chemistry lessons. Observing students' hands-on activities during chemistry lessons enabled researchers to monitor the development and expression of curiosity in the actual learning environment. The study involved 169 senior three chemistry students purposively selected from three intact science classes in three community secondary schools from Dar es salaam, Tanzania. We performed a Design-Based Research (DBR) in a convergent mixed method design following a pragmatic stance. We found that learners can better express their curiosity when they collaboratively learn using materials that they are familiar with. Besides, the paired samples *t*-test performed on the means curiosity indicators from pre and post-intervention Students Self-Reporting Questionnaire (SSRQ) gave $t\ (127) = 22.25$, $p<0.0005$, and the effect size of 0.80 while pre and post-intervention Teacher Rating Scale (TRS) shown $t\ (168) = 13.427$, $p<0.0005$ and effect size of 0.62. Based on these findings it is recommended that educators should put learners at the center of every step of the learning process through hands-on activities to stimulate their learning curiosity.

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Introduction

Activity-based learning strategies that embrace hands-on activities have gained a legacy in science and mathematics education in recent decades (Louca & Zacharia, 2012). Through hands-on activities, students acquire knowledge, apply the taught concept, and may develop a feasible solution to the problem (Hirça, 2013; Pirttimaa et al., 2015). Besides, activity-based learning is identified to consist of a range of pedagogical approaches in which learning is based on some hands-on and mind-on activities (Lui, 2012). By employing activity-based strategies, educators foster the 21st-century skills that learners ought to have for them to be successful academically (Louca & Zacharia, 2012). According to Fuad et al. (2018) and Hirça (2013), hands-on activities encourage the affection of lifelong learning as well as motivate learners to explore and discover new facts. Alkan (2016) and Pirttimaa et al. (2015) pointed out that when learners are fully engaged in hands-on activities they are likely to appreciate and learn what they are being taught. Holstermann et al. (2010) highlight further that well-designed hands-on activities focus learners on the world around them, spark their curiosity, and guide them through engaging experiences. Thus, activity-based learning strategies can promote authentic learning and allow learners to highly thrive for being better and true scientists.

Activity-based learning strategy has been proposed as a means to increase learners' understanding of scientific concepts through manipulating objects which may make abstract knowledge more concrete and clearer (Holstermann et al., 2010). Scholars identify a hands-on approach to be the instruction where learners are guided to gain knowledge and skills through experience (Hirça, 2013; Holstermann et al., 2010). According to Alkan (2016) and Sikandar, (2016), any relevant knowledge or information can be considered to be experiential as it somewhat relates either directly or indirectly to the prior experience of the individual learner. Therefore, when principles of learning by doing are applied concerning spontaneous activities of learners' experience, meaningful learning can be guaranteed.

A key goal of schooling and learning is to prepare learners for the world beyond school and transfer the acquired knowledge outside the classroom context. According to Lamnina and Chase (2019), this occurs when learners learn content deeply which mostly happens when they are highly curious. Highly curious learners are said to be sensitive to environments that value their preference for novelty, intellectual challenge, and growth potential (Kashdan & Yuen, 2007). Harackiewicz et al. (2016) and Lindholm (2018) demonstrated that school environments that support learners' desires to be independent learners are positively related to learners' effort, the persistence as well as coping ability. This kind of environment in turn can facilitate learners' engagement, interest and curiosity which may lead to greater academic success (Lamnina & Chase, 2019). Curiosity boosts the learner's ability to acquire and retain new information (Ruiz-Alfonso & León, 2019). Therefore, creating a classroom environment which can stimulate learners' curiosity should be the major focus of teaching and learning concerning the education challenges of the 21st century.

While a scientific consensus on how to define curiosity operationally has not yet achieved, Hon-Keung et al. (2012), Kidd and Hayden (2015), and Lindholm (2018) considers a state of curiosity to be mostly associated with the psychological drive for activities or stimuli that are surprising, novel, of intermediate complexity, or characterized by a knowledge gap or by errors in prediction (Borowske, 2005; Oudeyer et al., 2016). Ostroff (2016) argued that curiosity is a multi-dimensional concept that has no single definition and overlaps extensively with related concepts including creativity, inquisitiveness, and openness to experience. Nevertheless, Von Stumm et al. (2011) define curiosity as a form of intrinsic motivation that is key in fostering active learning and spontaneous exploration. Therefore, curiosity as a desire and drive for learning can aid the acquisition of knowledge in subjects like chemistry that are considered to be difficult by most learners (Overton & Randles, 2015).

Daniel Berlyne is widely regarded as the most influential contributor to theory and research on curiosity (Litman & Spielberger, 2003; Oudeyer et al., 2016). He did exploration and differentiated between two types of curiosity mainly perceptual and epistemic (Pluck & Johnson, 2011; Ruiz-Alfonso & León, 2019). The two types are major concern in this work, though other scholars have identified more types of curiosity. According to Von Stumm and colleagues, epistemic curiosity is referred to as, the individual difference in seeking out for engagement and acquiring knowledge (Von Stumm et al., 2011); whereas perceptual curiosity is induced by visual, auditory and physical stimulation towards experience and feel (Pluck & Johnson, 2011; Ruiz-Alfonso & León, 2019). Therefore, when a learner is stimulated towards a particular experience, a desire for engagement and acquisition of knowledge and skills can be achieved.

Chemistry, being the oracle of modern science, serves as a link between other science subjects such as physics, biology, and sometimes geography and mathematics (Nbina & Mmaduka, 2014). Chemistry is a fundamental subject, which applies to different careers and industrial processes. Högström, Ottander, and Benckert (2010) highlight that careers such as agriculture, geology, pharmacy and medicine among others are hinged on chemistry; hence individuals who seek accomplishments in these careers must have a good grasp of chemistry as a subject (Ngatijo et al., 2019). Overton and Randles (2015) argued that despite its importance, chemistry proves a difficult subject for many science learners. Scholars have asserted that chemistry curricula mostly incorporate abstract concepts (Bodner, 2015; Ngatijo et al., 2019), which are central to further instructions in both chemistry and other sciences (Högström et al., 2010). Hence, chemistry teachers should beware of the instructional strategies and procedures they use to deliver intended content (Ngatijo et al., 2019); so that meaningful learning of these abstract and complex chemistry concepts can be accomplished.

An experimental study was done by Opara and Waswa (2013) on "enhancing learners' achievement in chemistry through the Piagetian model" identified the mole concept among difficult chemistry concepts to most learners. However, despite the mole concept being difficult, they managed to get positive outcomes on learners' achievements in their experiments. In addition, the findings from Pluck and Johnson (2011)'s study on stimulation of curiosity to enhance learning revealed that the nurtured curiosity can be profitably employed to guide teaching practice in a range of educational contexts. These studies give a clue on the crucial impact of learners' curiosity on the learning process especially when knowledge is constructed from learners' experiences. Therefore, a good interpretation of human behavior and learner curiosity is needed especially in a range of educational contexts (León et al., 2015).

Some previous research indicated the importance of learners' curiosity (Jirout & Klahr, 2012; Kashdan & Yuen, 2007; Lindholm, 2018; Litman & Spielberger, 2003; Pluck & Johnson, 2011) and how it can be necessary for science education. However, despite curiosity being the important aspect of learning especially in science, it is indicated that little work is done in the context of education. Besides, the major achievement attained on the provision of quality education as stipulated in the fourth sustainable development goal SDG4 is that students can exhibit skills like curiosity. For these reasons, new empirical research on the development of ordinary level chemistry students' curiosity is presented in this paper. This research was done through assessment of the effectiveness of hands-on activities in chemistry lessons on the development of learners' curiosity.

Aim and Research Questions

This study aimed to investigate the effectiveness of hands-on activities performed using instructional materials designed from the learners' environment to enhance their chemistry learning curiosity. Therefore, this research answered the following questions:

1. How can hands-on activities be used to stimulate learners' curiosity during chemistry lessons?
2. What is the role of chemistry teachers in the enhancement of learners' curiosity through hands-on activities?
3. How can searching for instructional materials from a home-based environment play part to stimulate learners' curiosity?

Methodology

Research Design and Approach

This study was design-based research (DBR) in form of an intervention design (Bozkurt Altan & Tan, 2020), to bridge the gap between research, design, and practice (Gutiérrez, 2018; Scott et al., 2020; Štemberger & Cencič, 2016). DBR is considered to be a systematic but flexible research methodology that aims at improving educational practices through iterative analysis of a problem (Štemberger & Cencič, 2016), design, development and implementation of a solution, based on collaboration among practitioners and researchers in a real-world environment (Gutiérrez, 2018; Scott et al., 2020). Based on scope and focus of this study, only two phases of the first alteration circle presented in this work. However, this research employed a convergent mixed-method approach following a pragmatic philosophical world view (Creswell, 2014). The intent was to seek common understanding through triangulation of multiple sources of data from both qualitative and quantitative research approaches (Creswell, 2014; Mertens, 2010).

Participants

A total of 169 learners (101 boys, 60% and 68 girls, 40%) were purposively selected from three intact science classes of senior three in three different community secondary schools. According to the Tanzanian education system, senior three is the third year of the ordinary level of secondary education. The three community schools were also purposively sampled from 142 public schools in Dar es Salaam, which is the capital city of the United Republic of Tanzania. This total number of public secondary schools in Dar es Salaam includes 132 public secondary schools and 10 non-community schools. The selected learners had a mean age range of 16.12 with a standard deviation of 0.854. All 169 learners went through an intervention that enhanced their curiosity by empowering them to perform hands-on activities in chemistry lessons using learning aids from their home environment.

Research Instruments

Research instruments used for data collection in this research project were lesson observation schedule, semi-structured interview, and Focus Group Discussions (FGDs) guides for the qualitative part of the study, while the quantitative data was collected using Pre and post-intervention Students' Self-Report Questionnaire (SSRQ) as well as pre and post-intervention Teacher-Rating Scale on learners' curiosity.

The observation schedule was divided into five sections which are; planning, teaching strategy, instructional materials, indicators of curiosity, and learners' ability to develop learning aids. Under each section, some categories included detailed information for each lesson observed. Under part one, the observation focused on the way lessons were planned and introduced to students using a Competency-Based Curriculum (CBC). In the second part, the strategies that teachers used to deliver and facilitate the learning of the mole concept and volumetric analysis were observed. Besides, under each lesson observed, resources used by teachers and learners were identified. In all of these, our attention was centered on the way learners' curiosity was developed under teachers' guidance and learners interacting with hands-on activities. Lastly, our observation was based on learners' interaction and collaboration during hands-on activities carried out using locally made learning apparatus from their home environment materials.

The observation schedule, teacher interview guide, learners' FGDs guide were checked by different research experts for their accuracy and inter-rater reliability. The inputs made by the raters were incorporated before the instruments were used in the field. Also, the three instruments were piloted to check for clarity and whether the questions were understood by the respondents. In addition, SSRQ and teacher rating scales were piloted to check their reliability coefficients. Similar questions were asked in both pre and post-intervention SSRQ and teacher rating scales. The pre-tests were meant to test the level of students' curiosity before the intervention while the post-tests assessed the development of learners' curiosity after the intervention. The Cronbach Alpha reliability test results for the pilot studies were 0.83 for SSRQ and 0.72 for the teacher rating scale respectively.

The Research Intervention

Many researchers in the education context identify insufficient teaching and learning materials as well as inappropriate teaching strategies (Machumu, 2011; Nbina & Mmaduka, 2014) to be among the limitations of the provision of quality education. However, based on the urgent need for the provision of quality education, this research was designed to show the effectiveness of hands-on learning as an important part of any instructional model. The purpose was to empower chemistry learners with practical skills to search and design learning resources as well as perform hands-on activities in chemistry lessons, which can later enhance their curiosity for chemistry learning. This intervention was designed by the researchers and the practitioners who were chemistry teachers.

In addition, the intentions and success criteria for the intervention were (a) learners' participation in lesson preparation through searching of the instructional materials that corresponds to lesson content learned, (b) learners' ability to relate the content learned with materials in their surroundings, (c) learners' ability to manipulate the materials in the class to enhance their curiosity and (d) learners' ability to actively interact and collaborate with their peers and their teachers to enhance curiosity. The listed success criteria were the guidelines for learners to design and bring materials appropriate to the lesson content taught as listed in **(Table 1 and 2)**.

Table 1

Learning Aids and Hands-on Activities Performed for Mole Concept Topic

Topic	Sub-topic	Learning aids made from low-cost materials	Hands-on activities involved
Mole concept	Mole as a unit • Compare mole with other units • Measure molar quantities of different substances Application of mole concept • Convert known masses of elements, molecules, or ions to moles • Convert known volumes of gases at standard temperature and pressure S.T.P to moles • Change masses of solids or volumes of known gases to the actual number of particles • Molar solutions of various soluble substances • Calculations based on the mole concept and balanced equations	Different materials that can represent measures in kilograms pair, dozens, gross, distance, and time such as sand, water, pens, coins, Chart representing basic unit measurements	Group discussions Students in groups performing various measurements Group discussions on given activities related to mole concept calculations Individual students attempting the activities given on the boards

Note. S.T.P Standard Temperature and Pressure

Table 2

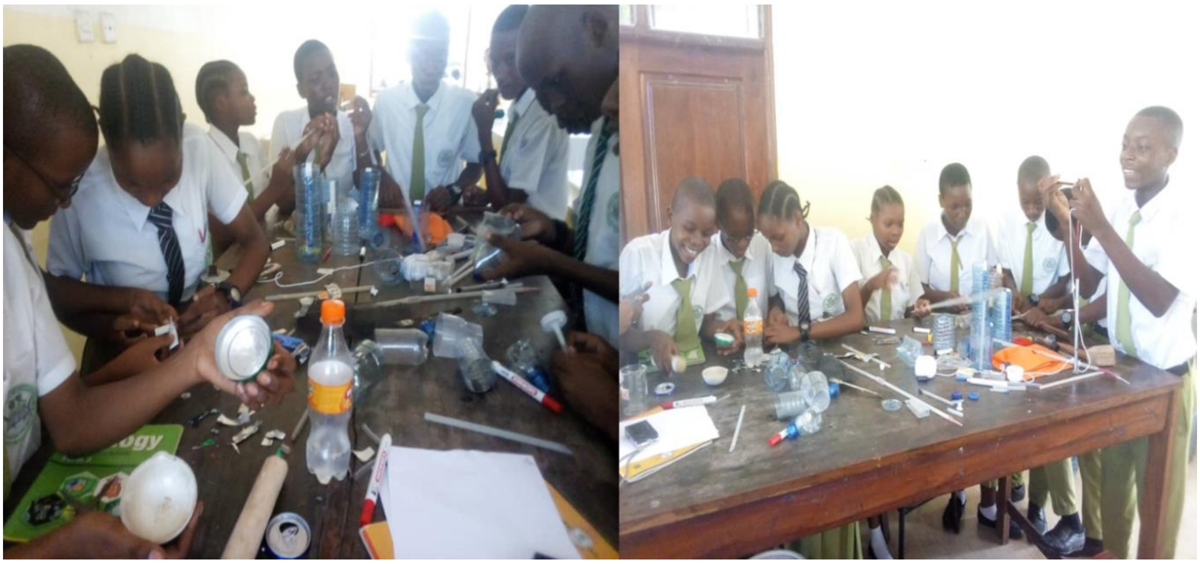
Learning Aids and Hands-on Activities Performed for Volumetric Analysis Topic

Topic	Sub-topic	Learning aids made from low-cost materials	Hands-on activities involved
Volumetric analysis	Standard volumetric apparatus • The concept of volumetric analysis • Use of volumetric apparatus Standard solutions • Steps in preparation of standard solutions • Acid-base titration • Standardize common mineral acids • Find the relative atomic mass of the unknown element in an acid or alkali • Calculate percentage purity of an acid or an alkali	Different apparatuses are made from local materials such as clothes pegs, syringes of different sizes, empty water bottles, rubber bands, white papers. These apparatus were worked as beaker, dropper, burette, funnel, white tiles Charts showing different apparatus	Practice using the locally made apparatuses Perform acid-base titration using locally made apparatuses Perform group activities on a calculation related to titration The individual trial attempt of titration related calculation

Students came into the class with already made materials from outside the classroom after orientation. The intervention was successfully done in two phases. **Figure 1** below is an illustration of students working in groups in the process of designing locally made apparatus.

Figure 1

Learners Designing Some Locally Made Apparatus During Orientation (Consented for Publication)



Data Collection Procedures

After obtaining the research permit from the responsible officials and three Principals whose schools participated in the study, consent was sought from both the chemistry teachers and senior three learners to voluntarily participate in this study. Then three days' orientation workshop was held between the researchers and the teachers to discuss the details of the study. The workshop discussions were aimed at discussing modalities for designing the intervention. During the discussions, teachers gave their views on how the intervention could be conducted to suit the context of their teaching environment. Besides, teachers practiced the use of locally made materials through micro-teaching among themselves so that it could be easier for them to introduce the whole process to learners. This was because the major and intended participants of the study were the students.

After the teachers' workshops, teachers taught the identified subject matter to their respective classes. At the onset of PHASE I of the intervention, learners who were involved in the study filled pre-intervention SSRQ to establish the level of their curiosity before the intervention. Apart from SSRQ, the teachers of these students filled the pre-intervention teacher rating scale to triangulate (Cohen et al., 2007; Creswell, 2014) the information given by learners in SSRQ. Also, learners were motivated and enhanced with the skills to use learning aids using low-cost materials from their local environments. A total of 24 lesson observations, 12 FGDs, and 12 teacher interviews were conducted in PHASE I of the intervention in all schools. Both the interviews and FGDs were audio-recorded and additional field notes were taken, too. Finally, at the end of PHASE I of the intervention, the teachers met for one day to share knowledge on the intervention as well as work hand in hand with the researchers to refine the designed intervention.

PHASE II of data collection continued immediately after the end of PHASE I. PHASE II has done in three weeks whereby a total of 18 lesson observations, 9 teacher interviews, and 9 FGDs have done in this phase in all three schools. At the end of PHASE II, learners and teachers filled post-intervention SSRQ and teacher rating scale to assess whether the intervention had any impact on learners' curiosity. In all the lessons observed, the researchers took a non-participatory position (Creswell, 2014; Houghton et al., 2013) to avoid influencing the process of data collection. Apart from that, both students' FGDs and teachers' interviews were semi-structured (Mertens, 2010) to ensure the flexibility of research participants and the data collected. Furthermore, the study being DBR did not involve a control group (Bakker & van Eerde, 2015). Therefore, all learners who were involved in the study were subjected to the intervention.

Data Analysis

The analysis of the data collected in this work was done concurrently with the data collection process (Creswell, 2014) daily. Constant reflection on the information obtained from lesson observations was done to monitor the ongoing process of data collection and identify issues that needed clarity and follow-up during the intervention process. All the qualitative data were analyzed thematically (Braun et al., 2016; Ormanci, 2020) where the whole process began by transcription of audio data, translation, and organization of the information obtained from the three instruments. Thereafter, the information was organized hand in hand with the field notes and data from classroom observation to develop raw data for the coding process (Yin, 2009). Then the coded information was sorted and sifted through to identify similar and coherent phrases (Braun et al., 2016), relationships between constructs, patterns, and themes to differentiate distinct and common sequences of categories about the research question (Creswell, 2014; Mertens, 2010). Lastly, meaningful information that gave a better interpretation of research questions was obtained from the developed themes and sub-themes (Nowell et al., 2017)

The analysis of quantitative data from SSRQ and teacher rating scale was done using the Statistical Package for Social Sciences (SPSS), version 20. The analysis involved descriptive (mean, standard deviation, and percentage) as well as inferential (dependent samples t-test and effect size) statistics (Cohen et al., 2007; Pallant, 2020; Reid et al., 2014). Further, the interpretation of the results obtained was done using the SPSS guide by (Pallant, 2020) to answer the proposed research questions.

Findings

Three themes were developed from the information obtained using lesson observation schedule, teachers' interviews, and FGDs. The three themes are as follows, teaching strategies (TS), Learning resources (LR), and development of curiosity (DC).

Theme 1: Teaching Strategies (TS)

One of the questions asked to teachers in the interviews required them to air out their views about the learner-centered teaching approach, which involves learners in different activities in chemistry lessons. Teachers at the beginning of the intervention mostly reported that the approach was good but it consumed time and their learners mostly relied on rote learning. Teachers preferred not to engage learners in learning activities to save time and to ensure the planned content for a particular lesson was accomplished.

For example one of the teachers commented that: *"when we use the learner-centered approach that engages learners in lesson activities; too much time of the lesson is consumed and sometimes the planned lesson content was not accomplished"*. **(Interview, Teacher C)**

Contrary to this comment both teachers and learners praised this teaching approach and hands-on teaching strategy a few weeks after the commencement of the intervention because according to the teachers it reduces teacher workload and increases learners' engagement in the lesson activities.

One of the teachers said that: *"engaging students in lesson activities enable them to take part in the learning process which also reduces our workload"*. **(Interview, Teacher A)**

Apart from that students emphasized that: *"teachers should continue to motivate us to participate in learning activities so that we can help one another to understand the lesson content"*. **(FGD, School B)**

This can be true because normally classes comprise students of different learning abilities. Nonetheless, based on the fact that hands-on activities were emphasized more in the course of the intervention. Both students and teachers were seen to appreciate the strategy with time and become accustomed to hands-on activities as productive teaching and learning strategies. For instance, learners in FGDs pointed out that learning by doing makes them active and become engaged in the learning process. The discussion below is the testimony to that as follows:

Researcher: *"How did you perceive hands-on activities when the strategy was introduced to you for the first time?"*

Puljet: *"For me, I used to find it difficult …because he was leaving us to perform everything."*

Researchers' follow-up question: *"Why do you say the teacher was leaving you to do everything? ...does it mean he was not giving you any guidance?"*

Puljet: *"He was guiding us but we were not used to that."*

Mjuni adds: *"You know our teachers used to teach and provide us with notes only….we were not involved in classroom activities before".*

Researcher: *"Then what happened?"*

Timothy: *"When you came everything changed."*

Jeremiah: *"For example, our teacher is telling us to bring learning aids …which was not happening before."*

Dativa: *"These days when the teacher comes in the class he does not use more time to teach…. But guide us to participate fully in our respective groups".* **(FGD, School A)**

Hands-on activities were mostly done in groups of not more than six students individual learners to participate in different activities within a respective lesson by cooperating with their fellow learners. These activities involved manipulation of the learning resources brought and made by students and discussion among learners with the guide of their teachers. Solutions for different chemistry activities that correspond to the investigated topics and sub-topics were derived among students themselves.

Theme 2: Learning Resources (LR)

It was pre-assumed that there could be varieties of learning resources in classes such as blackboard, textbooks, commercial materials, low-cost materials, and some IT resources. Yet, it was observed that materials mostly used in chemistry lessons were those that learners made and brought from their homes **(Figure 2 and 3).** Since learners had little experience of using textbooks due to their scarcity, they rather mostly relied on teachers' notes. Also, the teachers used different ways to introduce the lesson to prepare students for learning the intended content. Success criteria and learning intentions for a particular lesson were shared with students at the beginning of the lessons. In addition, at the end of every chemistry lesson teachers were accustomed to sharing success criteria and learning intentions for the next lesson to enable students to search for appropriate instructional materials from their home environment. Thus, when the planning of the lesson is well done, it enables students to endeavor to learn and teachers deliver the lesson well.

Besides, the designed intervention contributed much to learners working and making an effort to seek resources for their learning. Searching these materials forced students to read and discuss the respective content basing on the lesson objectives shared so that they can get appropriate instructional materials related to the particular content. The materials were designed in the classes collaboratively during orientation and later students did the whole process outside the classroom. Also, the intervention was planned to be implemented in this mode so that to avoid interruption of normal lesson routine.

When the majority of students in FGDs were asked whether they enjoy searching for their learning materials; these are what they said:

Farris: *"Searching for our learning materials is vital and it enhances understanding of lesson content… Because we are using materials that we are familiar with."* ***(FGD, School B)***

Monica: *"I agree with her… Using these materials in the class become like revising as we made efforts to understand the content related to these materials before searching and designing them from materials in our home environment".* ***(FGD, School C)***

Figure 2

Burette and pipette locally made by students

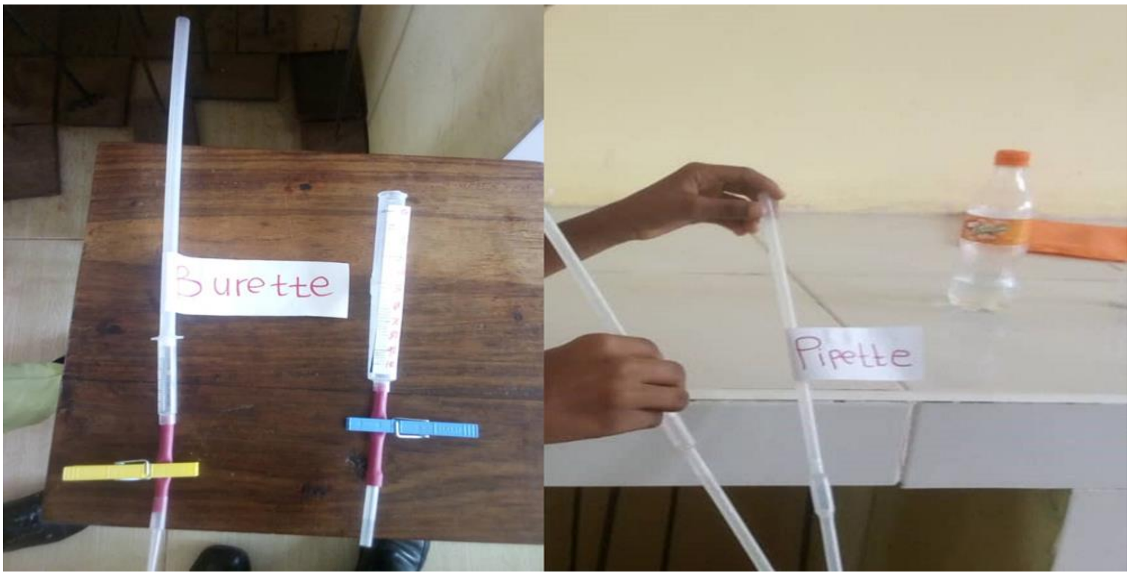


Figure 3

Locally Made Funnel and Beaker

while others invested much of their effort to make durable materials that can be used in other coming lessons. However, the extent to which chemistry teachers shared learning intentions and success c

Learners demonstrated different levels of their abilities to make learning aids from materials that can be easily obtained from their home environment. This was evident in the quality of the learning aids prepared. Some learners brought materials just for the sake riteria for the next lesson had a great impact on the learning aids prepared by students. When teachers shared the learning objectives clearly to learners with more clarifications, students made an effort to search for appropriate instructional materials. For some lessons where it was difficult to get materials to manipulate, learners used books to draw and give some examples on the manila sheets. Some of the learning materials prepared by the learners are listed in **Tables 1 and 2** above with their corresponding topics and sub-topics.

Theme 3: Development of Curiosity (DC)

Despite the mole concept being considered to be one of the difficult chemistry topics with abstract concepts, which learners seemed not to be interested in, the intervention gave promising results. This was revealed in most of the lesson observations done. Learners enjoyed interacting within their groups, manipulating the instructional materials made from low-cost materials as well as asking questions that was not their custom at the beginning of the intervention. Also, they were able to go beyond the teachers' guidance and expectations in a class by doing chemistry activities on their own without the guidance of their teachers. For instance, in school B the teacher did not instruct students to put an indication of volume on the designed beakers, but students reminded one another to indicate the calibration of volume on the sides of the beakers. This was verified by the teacher in the interview session *"I was surprised to see that some students remembered to label the beakers with the specific volume which I had not tell them to do"*. **(Interview, Teacher B)**

Teachers encouraged students to ask one another and help each other where they did not understand. Not only ask questions among themselves but they were also free to raise any query to their teachers during the lessons. Students asked questions for clarifications and/or explanations in cases where they wanted to know more. On one of the occasions, one student wanted to understand more on the concept of the number of mole and molarity and asked for the difference between 2 moles and 2M". Then, the teacher clarified by giving clarification and illustration on the chalkboard that; "when talking of moles it means the amount of substance, such that 2 moles are equal to (2 X 6.03 x 10^{23}) molecules/particles/atoms. But 2M means it is 2 moles of a substance in one litre, which means it is (2 X 6.03 x 10^{23}) molecules/particles/atoms in one litre. For instance, substances are things like water, salt, sugar, etc.". However, such kinds of questions that needed more clarifications were asked to teachers who provided satisfactory feedback. Therefore, this close relationship between students and their teachers encouraged students' active engagement during lessons and enhanced the development of curiosity.

Apart from the observations done, the information obtained from FGDs also revealed some element of elevation of learners' curiosity. The discussions were as follows:

The researcher: "*What can you say about the system of learning where you are involved in hands-on activities?"*

Gadi: "*It has taken time for most of us to get used to be involved in the lesson… But it has been the best experience for me because nowadays it's my pleasure to handle things on my own rather than waiting for others to do for me and just stand looking at them."* **(FGD, School C)**

Eunice: "*The same applies to me… This learning system has helped me to find out the ways to solve a problem by myself rather than being told how to do it by my fellow students."* **(FGD, School C)**

Kelvin: "*These days our chemistry teachers encourage us to be involved in discussions and cooperate in different activities of the lesson… In these discussions, I don't just sit and listen but it has been an opportunity to learn about new objects by touching them and relate them with what we learn from chemistry"* **(FGD, School A)**

One of the teachers complimented the information given by students as follows;

Teacher: *"Although much of the effort has been done to engage learners in the lesson and taking them through the process of searching for materials to be used in the lesson… I can boldly say that the effort done is worthy as you can personally witness the way my learners are now active in the lesson".* **(Interview, Teacher B)**

With time; interactive teaching methods like group discussions paired with some hands-on activities were adopted. Teachers allocated students in groups before the lessons based on students' needs andabilities as well as ensured gender balance. During the group discussions, students were observed to be able to solve some problems on given activities of the lessons within their groups and they were sometimes told to answer directly or make attempts on the blackboard. Also, individual students could collaborate with other group members to ensure that the apparatus was designed based on the learning intentions and objectives of a particular lesson. Besides, students were able to freely move around to check on the materials prepared by other peers and how they were able to manipulate the prepared equipment. Also, students were able to ask questions to each other for clarification. For example, in school C students from other groups wanted to know from their colleagues how they knitted well the materials to make durable pipettes and burettes. They went further and explored more on how they got the idea of using the clinical syringe to make well-calibrated burettes. This influenced us to purchase more clinical syringes of different sizes to be used by other students from other groups because their colleagues who had access to the syringes from their parents who were health workers had already paved the way. Nevertheless, both the teachers and students gave their views regarding this trend of the adjustment towards the hands-on strategy introduced to them, and below are their views:

Researcher: "*It has been a while now since you began to effectively involve your students in hands-on activities… What can you say about this teaching strategy? … Is it helpful to you and your students?*"

Teacher: "*Engaging students in lesson activities enables them to take part in the learning process which also reduces our workload*" **(Interview, Teacher B**).

Teacher: *"… As you can see these days my students do not need to be pushed to engage in the lesson. The emphasis we put on the use of hands-on activities in the lesson has been more helpful especially to engage students… Not only that but these days my students are now familiar with me than it was before"* **(Interview, Teacher C).**

The statements given by the teachers were complemented by the students is FGDs as follows:

Hongera: "*Teachers should continue to motivate us to participate in learning activities… So that we can help one another to understand the lesson content.*"**(FGD, School A)**

Khaitham: "*When we are involved in hands-on activities it is not only motivating us to learn but we must explore further what we are supposed to learn and think of the materials that will best fit with what the teacher told us to be learned in the coming lesson.*" **(FGD, School C)**

Mwanaasha: "*If this system continues it will not only help us in learning chemistry but also other subjects… By the way it will be better if teachers from other subjects learn from our chemistry teacher because as you can see we are now engaged in the lesson more than before.*" **(FGD, School B)**

Therefore, with the information given by both students and the teacher, it is assumed that the intervention contributed to the development of learners' curiosity because of the changes seen before and after the intervention.

In addition to lesson observations, the learners' FGDs and teacher interviews which were used to assess the development of learners' curiosity, pre and post-intervention SSRQ and TRS were used to obtain quantified information. SSRQ and TRS were meant to measure the level of learners' curiosity before and after the intervention. The overall score of students in pre-intervention SSRQ was (mean 3.17 ± 0.47 SD) while post-intervention SSRQ results were (mean 3.86 ± 0.30 SD) obtained from mean indicators in both pre and post SSRQ. The pre-intervention TRS results were (mean 2.86 ± 0.91 SD) while those of the post-test were (mean 3.80 ± 0.57 SD). The paired sample t-test performed on the means of indicators from pre and post-intervention SSRQ gave t (127) = 22.25, $p<0.0005$, and the effect size of 0.80 while pre and post-intervention TRS shown t (168) = 13.427, $p<0.0005$, and effect size of 0.62.

Table 3

A table of Paired Samples T-Test Showing the T-Value of Curiosity İndicators in SSRQ and TRS

		Paired Differences							
		Mean	SD	SE	95% *C. I* of the Difference		*T*	*df*	*Sig.*
					Lower	Upper			
SSRQ	Mean of indicators A – mean of indicators	20.766	10.561	0.933	18.918	22.613	22.246	127	.000
TRS	Post-test - pre-test	0.941	0.911	0.07	0.802	1.079	13.427	168	.000

The mean difference for both SSRQ and TRS in pre and post-tests reveals that there was a significant increase in learners' curiosity as a result of the designed intervention implemented through the use of learning resources designed from learners environment. Apart from that, also the effect size of both SSRQ and TRS confirms that there was a large effect size by giving a substantial difference in learners' curiosity before and after the intervention.

Discussion

In this study, an intervention of a hands-on instructional model was designed to enhance the development of learners' curiosity whereas; both qualitative and quantitative instruments were used to assess the effectiveness of the designed model. The results of this research are discussed in this section based on the relevant literature and how information obtained was triangulated to answer the proposed research question.

The findings obtained from lesson observation revealed that the way lessons are planned greatly determines the outcomes of the particular lessons. In other words planning of the lesson has an impact on how it will be introduced and presented to students and later determines the outcome of the lesson. According to the results obtained, teachers shared the success criteria and learning intentions of a particular lesson before and after the lesson to enable learners to be familiar with the lesson content and prepare for the lesson in advance. This can be done through proper and clear sharing of lesson objectives (Kanellopoulou & Darra, 2018; Yalcin Arslan, 2019). Lesson objectives include the learning intentions and success criteria of a particular lesson (Kanellopoulou & Darra, 2018).

The unique finding on the aspect of teachers sharing lesson objectives with their students was that before the intervention this was not happening in the classroom. But, this practice developed due to the effective implementation of the intervention. The learning intentions and the success criteria shared by chemistry teachers enabled learners to get well prepared for the incoming chemistry lesson, which also included searching for the appropriate instructional materials. This is like the teachers prepare their lessons in collaboration with their students. This finding is similar to what Yalcin Arslan (2019) reported that when teachers engage in such a process they can develop new understandings of the lesson that lead to changes in their teaching practices and meet the individual learners' needs. Therefore, sharing the lesson objective creates a shared learning atmosphere between teachers and students which can play part in stirring up the learners' urge for learning (Khoiriyah et al., 2015; Tukiran et al., 2017).

The second finding of this study was related to the instructional strategy employed in lesson delivery. The gesture shown by the learners on the reception and implementation of the hands-on instructional model designed signifies its vital impact on learners' drive to know more and exploration of the environment. Although hands-on activities which were carried out using instructional materials made from home-based raw materials was seen to have a significant impact on the development of learners' curiosity, the results of this study are not meant to substitute other learner-centered teaching and learning strategies. Rather, this work adds knowledge that can aid to improve educational practice (Ma & Harmon, 2009). When hands-on learning instruction is integrated into the process of learning, learners can interact with one another, share experiences, reduce the fear of trying and develop the inner drive (curiosity) to learning and exploration (Von Stumm et al., 2011). However, the ability of learners to explore their environment searching for their learning materials creates an independent generation that can transfer content knowledge into real-life experiences (Borowske, 2005; Tukiran et al., 2017). These learners will eventually meet the demands of the 21st-century growing world's economy.

In general, students seemed to be actively engaged in hands-on activities which subsequently stimulated their learning curiosity to learn. The effect size of 0.80 and 0.62 obtained from both SSRQ and TRS respectively verifies the changes that occurred on learners' curiosity due to the application of the hands-on intervention model that was designed. This is following Litman (2005) and Von Stumm et al. (2011), who highlight that when students are actively engaged in the lesson, they develop a hungry mind for learning, and the process of learning becomes of pleasure to them. This is also in line with Halpern (2016) and Hazzan et al. (2015), who demonstrated that active learning instructional strategies motivate learners to learn and enhance the transfer of knowledge from known to unknown. Therefore, involving learners in hands-on activities can not only enhance the acquisition of intended learning competencies (Marzuki et al., 2019) but also develop important skills like curiosity.

Moreover, another interesting finding of this study was on the way students were actively engaged in searching for instructional materials. Learners, being the primary consumer of what teachers prepare, were well informed on the essence of associating the lesson content with the materials in their surroundings based on the learners' needs (Tukiran et al., 2017). This is because when learners play part in their learning (Ostroff, 2016; Xhomara & Bara, 2020), the learning process becomes meaningful and students are enabled to invent and acquire new knowledge from their environment (Kanellopoulou & Darra, 2018; Ngatijo et al., 2019; Yalcin Arslan, 2019).

It can be observed from this finding that learners searching for instructional materials increase their familiarity with the concept to be learned and remain in a learning mood outside of the classroom environment. Not only that but also students working hand-in-hand with their teachers in lesson preparation reduce the workload of the teachers (Louca & Zacharia, 2012). This is more helpful especially in a context where a teacher has a large number of students in the class (Nbina & Mmaduka, 2014) which is, most of the time, the case in the United Republic of Tanzania as well as in other East African Countries (EAC). Therefore, the successful engagement of students in searching for appropriate learning materials is one of the teachers' achievements towards the attainment of desired learning outcomes.

Implications and Conclusion

We suggest that the use of a hands-on instructional model should be given priority by the secondary school teachers teaching chemistry in a similar context because of its nature and characteristics (Holstermann et al., 2010; Pirttimaa et al., 2015). Moreover, hands-on instruction has successfully shown to increase learners' engagement in the lesson inside and outside of the classroom environment through searching for instructional materials appropriate for their learning. Also, in essence of enhancing the intervention designed in this study to bring results that are more practical in education contexts with a similar learning environment to the study sample, researchers and educators in the field of education should think of implementing the intervention further. Moreover, future studies ought to integrate the study into a large sample of the population for its generalizability. Regarding the limitations, this study was limited to only three community secondary schools. It can further be extended to other rural, urban, public and private secondary schools to investigate the relationship.

The significant implication of this study is the emphasis done on developing learners' curiosity in the context of education. The findings of this research are evident and encouraging as they indicated how curious students can be and to which extent they can express their curiosity when exposed to hands-on activities. Furthermore, it is evident from the findings that the implementation of the model used in this study helped students to practically channeling their curiosity in the association of the content learned with the surrounding environment. Therefore, an intriguing path for further study would be to explore the association of learners' curiosity with their ability to comprehend lesson content as a result improves their performance.

In conclusion, it can be stated that engaging students in the lesson preparation process is paramount and it is effective in stir-up learners' desire for learning. This can be done through learners' familiarization of the lesson content with their home environment and prior experiences. Also, the learning process becomes more interesting when its facilitation is done using materials that are of learners' preferences. Finally, engaging students in hands-on activities can be considered as one of the ways which can best develop students' curiosity. Therefore, it is time for researchers in the context of education to think of doing more studies on learners' curiosity to enhance their understanding of learners' inner drive for learning and exploration.

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