RELATIONSHIP BETWEEN THE USAGE OF EQUIPMENT DESIGNED FOR RIGHT-HANDED PEOPLE AND ATTITUDES TOWARDS CHEMISTRY AMONG LEFT-HANDED HIGH SCHOOL STUDENTS IN KENYA

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ABSTRACT

Research into left-handedness concurs that generally, left-handed people experience difficulties manipulating right handed tools. Specifically, left-handers face challenges associated with right handed instructional resources because of their inherent peculiarities due to their hand orientation in science classrooms. There is evidence for a general cognitive disadvantage for left-handers compared to right-handers according to recent research. Studies have explicitly shown that left-handed learners are disadvantaged when using mismatched instructional resources that are generally 'ungraspable', and more so during chemistry laboratory timed tasks. Whereas the importance of practical work in science cannot be ignored based on its significance to learning school science, adaptations left-handers have to make so as to fit with right handed instructional resources gets in the way of their learning. A persistent failure to effectively interact with the resources fluidly lowers learners' self-efficacy thereby causing them to harbor negative attitudes and interest towards chemistry. This comparative case study assuming a mixed methods concurrent triangulation design sought to find out the relationship between left-handers' use of right handed instructional resources and their attitudes towards high school chemistry. Participants were drawn from a cross-section of secondary schools in Kenya. Left-handedness was determined using the Torque test for handedness. Quantitative data was collected by use of questionnaires. Qualitative data was collected through focus group discussions. Qualitative data was analyzed thematically while quantitative data was analyzed using SPSS. The final report had contextual description and direct quotations from the research participants, a statistical significance of findings, correlations, and comparisons of means. Suggestions to instruction designers to generate instruction designs that encourage low cognitive load were made. Practical suggestions to instructors on the best practices when instructing left-handed learners during chemistry practical sessions were also highlighted. The findings served to contribute to existing literature on special learning needs, enlightening education stakeholders to embrace the unique needs of left-handed learners. *[African Journal of Chemical Education—AJCE 5(2), July 2015]*

BACKGROUND INFORMATION

Attitudes have been defined in a variety of ways. For example, Smith, Walker and Hamidova [1] define attitudes as containing feelings and emotions associated with objects and are assumed to result from one's prior experience with the object. Sarnoff [2] sees an attitude as a disposition to respond favorably or unfavorably to an object. Apparently, these definitions are aligned with behaviorist perspectives that explain the behavior of individuals based on their previous undertakings in their surroundings in general. Therefore attitudes are not innate but learned, suggesting some past experience with the object [3]. Attitudes towards science have been defined by Gardner [4] as a learned tendency to appraise in definite ways objects, people, actions, situations or propositions involved in the learning of science. These attitudes are known to involve attitude objects such as "science" or "science lessons," "laboratory work" and so on [5]. When the response to either of these objects is favorable, students are said to have positive attitudes and when the response is unfavorable, students are said to exhibit negative attitudes. It has been postulated by Hofstein and Mamlok-Naaman [6] that in order to help learners develop positive attitudes towards and interest in science in general and learning science in particular is one of the key goals for teaching and learning school sciences. This study adopts attitudes as learned predispositions to respond in a consistently favorable or unfavorable manner to a given subject as is consistent with Gardner's [4] definition of attitudes.

Students develop attitudes toward science, for example, by openly seeking information to respond to an immediate need. An individual student holding a favorable attitude toward science could be expected to do well in science tasks, look forward to science lessons and laboratory sessions, or even choose to pursue science related careers. Once individual's predisposition or attitudes have been established, it is expected that they will (or will not) perform the associated behavior [1,7]. That means positive experiences tend to build self-efficacy in carrying out a task. However, the contrary also holds.

Research on psychological effects has found that students' self-efficacy of ability to perform in science positively correlates with achievement [6]. It has been observed that many students fear chemistry, a fear characterized by mass disenchantment among students towards the subject. The end product has been the declining popularity of chemistry over the years. According to Keeves and Morgenstern [8], students' anxiety towards the learning of science makes them lose interest in the subject. On the other hand, Deboer [9] points out that students' achievement is influenced by favorable attitudes towards oneself (positive self-efficacy) as well as the subject. A student with positive self-efficacy of ability in a subject has a higher probability of developing favorable attitudes towards that subject, and as a result spends more time and energy in the subject thus gaining mastery of the subject which results in improved achievement. Deboer [9] further argues that as a result of this success, the student is reinforced further to continue performing well in the subject possibly developing stronger favorable attitudes towards the subject.

A number of factors have been found to influence attitudes in general. For example, Giallo and Little [7] carried out a study in Australia with graduate and student teachers in order to assess the differences in self-efficacy in behavior management between training. Attitudes were found to not only be influenced by the belief that a particular action will lead to desirable outcomes but also by the belief that one has the ability to perform that action. According to Mwamwenda [10], a person's self-efficacy is a guide to their personality in terms of their own feelings, attitudes, psychological health and the way they are likely to interact with other individuals in their environment. Therefore students with a positive self-efficacy are better inclined to improve their performance compared to students' with a negative self-efficacy of ability. It follows that the enhancement of positive self-efficacy of ability of students' in science will possibly enhance their performance by fostering development of favorable attitudes towards the subject.

Teacher support has also been shown to influence students' attitudes toward a subject. When students feel that their teachers are supportive, enthusiastic about the subject and content and are willing to help them, they tend to devote more time studying the subject [1]. This is in tandem with Fraser's [11] assertion that students' positive attitudes are correlated to teachers' support, interest, innovative pedagogical approaches and the opportunity to involve students in their learning. A study by Malusi [12] established that left-handed students appreciate teachers' support more compared to support from their peers, especially during laboratory sessions when they get help in order to cope with instructional resources in these laboratories.

Learners' Attitude towards Chemistry

The interest of earlier studies has been focused on the intervening factors between subject grade level and performance in science-related attitudes [13]. The world over, there has been an interest in the development of positive attitudes among students towards learning school science [14] and the objective of any science curriculum would include fostering favorable feelings towards learning of science as well as imparting cognitive knowledge. This is because attitudes associated with science appear to affect students' participation in science subjects as well as impacts in science [15]. Across the years of secondary schooling when science is a compulsory subject, research studies from a range of countries show a decline in students' positive attitudes towards school science [see 16, 17, 18, 12]. It has been established that the prevailing factor that affects students' willingness to study further chemistry is a negative attitude towards it [19].

Interest has long been recognized as an important motivator of learning [20]. In the recent past, research has however reported a trend of declining interest in science among young students across grades, suggesting that school science has not effectively fostered student interest [21]. For example, Belge-Can [19] in his study that investigated the effect of grade level on high school students' attitudes toward chemistry across grades in Turkey found that student' attitudes change across grade levels in terms of both "enjoyment of chemistry" and "importance of chemistry" constructs. This finding suggests that if students are given an opportunity to connect the importance of chemistry to their future lives then, even those with low expectations can still perform in chemistry. This is in agreement with Schwartz-Bloom, Halpin and Reiter [22] claim that "… when students with relatively low expectations for success in science are asked to connect the relevance of their science topics in class to their lives, they display more interest and perform better in science" (p. 744).

Teaching and learning of science involves laboratory sessions. Here, students undertake practical work in order to obtain laboratory skills such as the manipulation of equipment for the collection and interpretation of experimental data. Attitudes are inevitably formed during such laboratory sessions. The relationship between laboratory work and attitudes was scrutinized by Kurbanoglu and Akin [21] in a study that examined the relationships between chemistry laboratory anxiety, chemistry attitudes and self-efficacy among Turkish university students. There were three hundred and ninety five students (236 females and 159 males; m=20.9 years) in the study. Findings revealed that self-efficacy directly affects chemistry laboratory anxiety and attitudes and students low in self-efficacy are more vulnerable to chemistry laboratory anxiety and negative chemistry attitudes. This means that learners may effectively belief that they can undertake a task according to the specifications laid down in the given time frame. But according to Millar [23], a persistent failure to meet expectation despite learners' capability to do a task leads to low self-esteem and eventually a negative attitude towards the subject is developed.

The significance of gender and learning school science has also elicited interest in earlier studies. In a study by Barmao [14] that sought to determine the differences in performance between boys and girls in secondary school science subjects, participants included 300 form three boys and girls from a cross-section of schools in Kenya. Findings showed that fewer girls compared to boys excel in science while majority of them underachieve. It was also shown by Karanja [24] that fewer girls than boys continue with the study of science and related courses at higher levels of education and that girls are underrepresented in areas requiring certain qualification in sciences in Kenya. In their study, Inzahuli, Elizabeth and Lazarus [25] sought to determine the gender disparities in self-efficacy, attitude and perception in Physics and Chemistry among high school boys and girls. Findings revealed that boys reflected better academic achievement compared to girls in both Physics and Chemistry. The boys and girls had comparable self-efficacy in Physics but girls had a higher self-efficacy in Chemistry than the boys. This may suggest that self-efficacy does not influence performance in Chemistry since boys outshone girls in spite of the girls' higher self-efficacy.

Further afield, studies that have investigated gender differences in students' attitudes toward chemistry courses have shown similar trends. A quantitative study by Cheung [26] examined the interaction effect between grade level and gender with respect to students' attitudes toward chemistry lessons in secondary school. There were 954 students of chemistry (ages 16 to 19 years) from a wide spectrum of socio-economic backgrounds with a large diversity in intellectual ability in Hong Kong. Findings indicated that the interaction effect between grade level and gender on students' attitudes toward chemistry lessons was statistically significant.

Male students in the study liked chemistry theory lessons more than their female counterparts, a liking that declined when the students progressed across the grades. Overall, all participants were just marginally positive about chemistry lessons during the years of secondary schooling.

High school chemistry is a highly interactive subject that requires the manipulation of apparatus in the laboratory. A cross-section of researchers have established that learners across all ages have negative attitudes towards chemistry. For example, a study on gender differences in secondary school in Israel by Hofstein et al., [16] on 11^{th} and 12^{th} graders revealed that girls had a more favorable attitude towards studying chemistry than did boys. In Australia Shannon, Sleet and Stem [27] reported that girls found chemistry more enjoyable than did boys. Contrary to these studies, Menis [28] in USA, Harvy and Stable [29] in the UK and Barnes, McInernery and Mash [30] in Australia revealed that boys' attitudes towards chemistry was more positive than that of girls. Elsewhere, learners from other countries for example, Turkey [17, 21], Nigeria [18] and Greece [13] all yielded similar results, that is, boys posses more positive attitudes towards chemistry compared to girls. Kurbanoglu and Akin [21] further established that there is a positive relationship between chemistry laboratory anxiety, attitudes towards chemistry and self-efficacy. The inconsistencies seen in their studies are related to the type of measure used by the researchers, the nature of the content and the chemistry curriculum, the instructional techniques often used in the chemistry classrooms, and the students' grade-level [31].

How Students Learn Chemistry

Chemistry learning is a highly interactive activity. Students not only interact with the subject content cognitively (minds-on) but also through practical work (hands–on) during laboratory experiments. The cognitive information processing (CIP) theory opines that learners can only process a few pieces of information at any one given time [32, 33]. Depending on the level of processing and the attention paid to it, information proceeds to the sensory memory, working memory (WM), short-term memory (STM) and long-term memory (LTM) [34]. For information to be registered in these memory stores it must be attended to and any information that is not paid attention to is lost [34].

The STM store receives information from the environment for processing. It also receives the retrieved information from the LTM to facilitate the execution of a function. However, the STM store has a limited information storage capacity of 7±2 items without rehearsal [33] implying that an individual must chunk information that contains more than 7 items to avoid losing it. The problem is that chunking ought to be done according to some kind of logic to facilitate effective storage yet during learning the learner may not have the luxury of time to devise the logic for chunking.

When the quantity of information is large, cognitive overload arises. As outlined by Sweller's [32] cognitive load theory (CLT), learning content comes with different types of cognitive loads vis a vis intrinsic, germane and extrinsic loads [32]. Intrinsic load constitutes intended information for processing, germane load constitutes the instructions that accompany the information such as the objective for processing it and how it should be processed while extrinsic load constitutes the noise in the information (Sweller, 1988). In other words, extrinsic load tends to create unnecessary competition for the cognitive resources during information processing.

In most cases, information is first processed by the STM in order to be stored in long-term storage [34]. Yet with the STM's limited capacity [33], the unnecessary cognitive load such as the extrinsic load may become a hindrance to the effective processing of the intended information [32]. Any information overload will therefore most likely lead to loss of information or difficulties at processing it for storage in the LTM. Failure to store such information in the long-term store (the permanent storage of information) means that the learner will most likely have limited resources for retrieval [32].

This overload will also influence the retrieval of whatever information is stored in the LTM because the WM which is largely useful with regard to retrieval functions also has a limited capacity similar to that of the STM [35]. This means that information from the LTM is briefly held there as the STM processes the incoming information in the central processing unit which is the link between incoming information from the environment and that from the LTM. In case the WM and STM are both overloaded, there is a high likelihood for the processor to get a wrong interpretation of the stimulus due to limited information.

To avoid overloading the memory and hence hindering proper information processing, the mind has adopted the process of automating procedural knowledge. Once automated, this knowledge is simply processed unconsciously while attention is focused on processing information in the incoming stimulus for storage and accurate interpretation [36]. This might not be the case where the STM is overloaded by processing information that ought to have been automated and therefore unconsciously processed. In order to effectively process the large amounts of information that are associated with practical work, it is necessary that some of the knowledge and skill is automated [37, 38]. This automatization frees cognitive resources from being overloaded [see 37] and the learner can then handle information that requires conscious efforts effectively.

Needless to say, during teaching and learning, all individual differences need to be understood and factored in because in most classrooms, they not only exist, they affect learning. In tandem with the Education For All (EFA) goals and the Convention for the Rights of the

Child Article 3 (1) [39] which reads in part "… the best interests of the child shall be a primary consideration" (p. 2), it is the right of every child to be treated fairly in educational settings despite their unique needs. This includes paying particular attention to left-handed students who have to handle instructional resources meant for right-handed learners and at the same time reach their threshold.

The Chemistry laboratory: A unique learning environment

Laboratory activities have long played a distinctive and central role in the science curriculum and science educators have suggested that many benefits accrue from engaging students in science laboratory activities [40-44]. More specifically, they suggested that when properly developed, designed, and structured, laboratory-centered science curricula have the potential to enhance students' meaningful learning, conceptual understanding and their understanding of the nature of science.

Literature has shown a clear correlation between students' attitudes towards learning science and various modes of instruction in the science laboratory [6]. In a literature review by Hofstein and Lunetta [40, 43], it was reported that students enjoy laboratory work in some courses and that laboratory experiences result in positive and improved attitudes and interest in science. It was also reported that chemistry students found personal laboratory work (hands-on) as the most effective instructional method that they experienced for promoting their interest in learning chemistry when contrasted with group discussion, teacher's demonstrations, filmed experiments, and teacher's whole-class frontal lectures [45]. Further, a greater degree of participation in laboratory work may produce more positive attitudes towards the laboratory work [46]. On the other hand, Milner, Hofstein and Ben-Zvi [47] found that students' enrollment in post-compulsory courses in high-school chemistry was due to students' ability to participate in practical activities in the chemistry laboratory thereby gaining valuable experiences. Therefore the decision to study (or not study) optional subjects e.g., chemistry is a partial attitudinal indication [6].

How Left-Handed Students Learn in the School Laboratory

The aspect of handedness is very important to the manipulation of instructional resources during timed tasks. To find out the effect of handedness in carrying out a bimanual coordination test, Ruecker and Brinkman [48] sampled 13 left-handers (8 women and 5 men, mean age = 27.8 years) and 15 right-handers (9 women and 6 men, mean age = 28.7 years) for their study. Participants were required to draw lines at various angles on an Etch-a-line by simultaneously manipulating two knobs, one on the left, which moved the cursor horizontally, and another on the right that moved it vertically. The angle at which they were to draw the line was indicated by parallel guidelines drawn on a transparency overlaid on the Etch-a-sketch.

The task involved turning the left and right knobs at an equal rate while drawing 45^0 and 135^0 lines. For 22.5^0 and 157.5^0 angles, participants had to turn the left hand twice as fast as the right. For 67.5^0 and 112.5^0 angles, participants were to turn the right hand faster than the left. For the leftward oriented lines ($x>90^0$), the left hand was to be turned counter-clockwise and the right hand clockwise. For the rightward oriented lines ($x<90^0$) both hands were to be turned clockwise. Each participant was allowed two trials for each angle. For one trial, they could see the line as it was drawn while for the other, a barrier was placed over the screen after half the line had been drawn. Participants were required to continue drawing without seeing the line. In-sight trials always preceded out-of-sight trials.

Results indicated a main effect of handedness; for lines not within the guidelines, left-handers made more errors than right-handers (left-handers' mean =0.86 inches, right-handers' mean =0.41 inches). There was a main effect of angle that was modified by handedness by angle interaction. Left-handers were slower than right-handers for lines oriented at 22.5^0, 45^0 and 67.5^0. These were the lines which required clockwise turning by both hands. The 67.5^0 line also required that the right hand turns faster than the left.

The conclusion was that left-handers have trouble coordinating the movement of the right and left hands. The researchers suggested that the anterior callosum found in left-handers may reflect the additional processing load required in some left-handers when motor programming does not take place in the hemisphere controlling the movement. Due to this predisposition of left-handers, the struggle with teaching/learning instructional resources during manipulation of the same in timed task settings may result in frustrations and a probable negative attitude towards the task and/or the subject.

In another study whose aim was to determine the categorical differences inherent between right and left-handed individuals and how they affect the way they learn, Parish [49] sought to ascertain whether left-and right-handers can learn a skill effectively when seeing a demonstration from an opposite handed instructor. The task involved demonstrating a lacrosse[1] shot to the participants (69 college-aged students), equally split between male and female, left- and right-handed. Half of each group saw a left-handed demonstration and the other half saw a right-handed demonstration. Participants were assessed on target accuracy and four components of shot form. Left-handers performed significantly better compared to right-handers on target accuracy ($F(3, 68) = 4.38$, $p=.007$), shot form ($F(3, 68) = 2.87$, $p=.043$) and body positioning ($F(3, 68) = 4.51$, $p=.006$). Parish concluded that left- handed college students appeared better able

[1]Goal game in which players use a triangular-headed long-handled stick with a mesh pouch for catching, carrying, and throwing the ball

to collect important information from an opposite-handed demonstration, an attribute that lacked in right-handers.

Demonstration as a teaching methodology and as it applies to the acquisition of gross motor skills has become a central teaching template for instruction [49]. In as far as watching an opposite handed demonstration in the school laboratory is concerned, a study by Malusi [12] established that left-handed high school students (17-19 years) preferred watching a demonstration from the same side as their right-handed teacher. This, the learners argued, made them ‘understand and follow demonstrations with ease’.

This far it appears that paying the desirable attention by younger left-handers during a right handed demonstration may not be enough. This is because most of the time is spend reversing instructions and observing procedures [50]. As a consequence therefore, the effective creation of mental images and motor learning may not occur due to increased information processing required. Essentially, this leads to failure to store the required information in the memory stores effectively. Mental imaging and continuity for future attempts to reproduce and perform the observed skill does not happen as well because most of the incoming information is lost. The additional processing load has been taken to be responsible for the increased cognitive load (CL) that left-handed learners have to deal with during learning [48].

A theoretical case was advanced by Rouet [51] that given a specific task and specific materials, CL is obviously subject to variations as a function of learner characteristics, such as their memory capacity and the interacting elements. For example during learning, students are sometimes faced with the task of understanding some intellectually difficult material that requires considerable time, effort and thought. The learner has to engage certain mental processes and instructional procedures and designs that would best facilitate the learning which, according to Pollock, Chandler and Sweller [52] in order to facilitate understanding they tend to in-corporate all the information elements required for understanding in the instructions. Frequently, these types of instructions may overwhelm a learner's limited WM and hinder effective learning.

Why Mismatch of Resources Affects Self-Efficacy Belief in Chemistry Learning

Numerous studies have been carried out in the context of attitudes and mismatches in the learning of science. It has been established that students subsequently develop negative attitudes towards science because there is a mismatch in the learning environment. For example, studies by Dhara, Khaspuri, and Sau [53], Parish [49] and Malusi [12] showed that mismatches experienced in learning environments have a negative effect on learning outcomes. Ruecker and Brinkman [48] found that left-handers have difficulties coordinating the movement of the right and left hands simultaneously, especially in tasks that require clockwise turning by both hands. More often than not, when left-handed learners handle and manipulate mismatched resources, instead of deploying the cognitive resources to consciously process the information that is supposed to be learned such as the task at hand, the learners' efforts will be directed to processing extrinsic load generated by consciously processing what ought to be unconsciously executed. As a result, the intended content for learning will not be effectively processed for storage in the LTM for future retrieval in response to new situations [32, 35]. The failure to process and retrieve the required information effectively may lead to the development of negative attitudes about their abilities.

On the other hand, the persistent failure to effectively manipulate instructional resources that front challenges to left-handers because they are mismatched to their physiology can lead to a ripple effect that changes the way in which the learners interact with laboratory apparatus. This also causes lowered self esteem which may lead to the development of negative attitude toward laboratory tasks and the subject, eventually making the learner to harbour unfavorable attitudes towards chemistry and thereby affecting their academic achievement.

THE KENYAN CHEMISTRY CURRICULUM

The educational system in Kenya includes three years of early childhood, eight years of primary school, four years of secondary school and a minimum of four years of university education, hence the 8-4-4 system of education. Primary school constitutes the cycle of compulsory free education. All learners study chemistry under the combined science discipline, taught everyday for 35 minutes. In secondary school, chemistry is taught for four 40 minute periods per week in junior high school (form one and two) and five 40 minute periods per week in senior high school (form three and four). Students wishing to take up advanced chemistry courses at the university after form four must attain 10 points on a 12-point scale to get admission in the public universities.

In the first year of junior high school, chemistry curriculum follows a macroscopic to microscopic approach. This approach refers to instructional methods that use examples of real-world or demonstrations to introduce chemistry topics followed by microscopic explanations using two-dimensional drawings of dots and circles to represent atoms, ions, and molecules [54, 55]. Chemical symbols are introduced as the language of chemical communication. Students are only asked to recognize the chemical symbols of the first twenty elements of the periodic table. For example, students recognize the symbol “H_2O” and “MgO” as the chemical way of writing “water” and “magnesium oxide” respectively. In the second year of junior school, students are taught how to balance simple chemical equations.

In senior school, chemistry curriculum emphasizes a linear development of chemical concepts with a symbolic approach. This refers to instructional methods that start from subjects that introduce first basic theoretical concepts of atomic theory and bonding on the microscopic level and proceed to subjects focusing on the macroscopic level [54]. Symbolic approach refers to instructional methods that use chemical and mathematical symbols and equations to represent matter [55]. Students use chemical symbols to describe a chemical process as well as to extract the qualitative and quantitative information provided by a chemical formula.

The curriculum in Kenya is centralized in that the government not only determines the national curriculum standards and content, but also centralizes the textbooks, the teaching materials, and the pace of teaching. All schools in Kenya that offer the 8-4-4 system of education must follow the same curriculum and use the same educational materials authorized by the Ministry of Education. Laboratory chemistry courses are also included in the curriculum.

The end of form four chemistry examinations comprises of two paper/pencil theory papers and a practical paper coded 233. Paper 1 (233/1) is a short answer paper/pencil, usually marked out of 80 marks and lasts 2 hours. Paper 2 (233/2) is a long answer paper/pencil, consisting of 8 questions each of 10 marks and lasts 2 hours too. The practical paper (233/3) on the other hand is marked out of 40 and lasts 2 hours, 15 minutes. The 15 minutes provided by the examining body, Kenya National Examination Council (KNEC) is used making sure that the provided requirements are adequate and in perfect working order before the examination starts (KCSE Exam Timetable, Instructions & Guidelines).

During timed laboratory sessions, the practice in Kenya is that the working station is prearranged for task takers. This prior arrangement is done with right-handers who constitute about 90% of any random sample in mind [56]. Therefore, left-handed learners have to consciously make adjustments during handling and manipulation of some selected instructional resources during such sessions. Sometimes they have to change positions and/or rearrange the resources in order to comfortably take the task. No extra time is allowed for these adjustments yet they eat into task time [12]. This disadvantage increases extrinsic cognitive load for left-handed learners.

In Kenya like in many other parts of the world, left-handedness has never been regarded as a special learning need. In that case, all students are exposed to the same instructional resources despite the fact that 10% of any randomly sampled population is left-handed [56]. It therefore follows that there is a mismatch between instructional resources and learners physiology. Since this mismatch has theoretically been shown to impact attitude elsewhere, it was on this backdrop that this study was premised. The study aimed at investigating attitudes toward chemistry among left-handed high school students in Kenya. By “attitudes toward chemistry” the researcher refers to positive or negative set of beliefs towards chemistry. In particular, the study intended to investigate whether the use of right handed instructional resources influences left-handers’ attitude towards the learning of high school chemistry.

METHODOLOGY

This section covers the research design, sample and sampling procedures, instrumentation and data collection procedures. Data analysis procedures, ethical considerations and study limitations are also discussed.

Research Design

This was a comparative case study that assumed a mixed methods concurrent triangulation design [57]. This method was preferred because in the recent past there has been an ongoing debate concerning limitations of educational research due to traditional reliance on a single research paradigm [58]. Mixed methods model generally uses separate quantitative and qualitative methods as a means to offset the weaknesses inherent within one method with the strengths of the other [57]. Benefits associated with the use of mixed methods approach include; triangulation of findings, (enhancing the validity or credibility of findings), facilitation (using results of one method to help develop the instrumentation for another), and complementarity (extending the comprehensiveness of findings) [59, 60]. Generally, one of the two approaches dominates and the other is secondary and supplements it. Integrating social science disciplines with quantitative and qualitative approaches in the research process [57] strengthened the reliability of data, validity of the findings and recommendations, as well as broadening and deepening the understanding of study questions [59].

Comparative case study approach seeks to establish the comparability of two different sets of data over the same dependent variable and therefore the need for control is high just as it may be expected of an experimental procedure. For the current study, comparability of the cases was determined on the basis of the factors that the theory and literature review had been established as being capable of influencing the findings. These include learner's age, teaching/learning experiences and gender. This ensured that the only attribute that was likely to influence the learners learning outcomes and attitude towards chemistry was their handedness. At the same time, it was assumed that this was the single most attribute that was likely to cause the difference in the results observed about attitudes towards chemistry. Additionally, if case findings indicated that handedness did not necessarily affect attitude, then the researcher had the opportunity to extent her investigation to other variables of comparability.

One of the challenges any researcher will face in applying case study is in the selection of samples. This is because the universe of the cases to be sampled is usually unknown. Therefore, procedures such as random sampling techniques were automatically ruled out. Since the researcher intended to identify participants that differed on handedness, which was the attribute hypothesized to influence the attitudes toward chemistry, it demanded that she had to engage a sample selection procedure that ensured comparable distribution of both left- and right-handed participants.

Sample and Sampling Procedures

The target population for this study was fourth form students (ages 17-19 years) enrolled and registered for chemistry in the Kenyan Certificate for Secondary Education (KCSE) examinations. For the purpose of comparability, the students in this population were comparable across parameters such as cognitive ability in chemistry, age, experiences and prior knowledge. This was mainly because the students were selected according to certain criteria to join secondary schools.

The population was stratified according to male/female, left-/right-handed students of chemistry. For purposes of comparability, the sample constituted an equal number of right-handed and left-handed male and female students of chemistry. The number of left-handed, both male and female determined the number of their right-handed counterparts selected for the study. Participant teacher(s) constituted the students' teachers of chemistry.

All left-handers were purposively sampled. Right-handers for the survey were randomly sampled while the matched random sampling procedure based on students' performance in chemistry was used to select those who participated in the focus group discussions (FDG). The procedure for matched random sampling was applied where two samples in which the members are clearly paired and matched according to a known construct in this case performance in chemistry. For the quantitative sample, a multistage sampling was used. In this case left-handers were purposively sampled while right-handers were systematically sampled.

Participants for the qualitative data were drawn from form four only. This was because the FGD questions sought to find out the students experiences when they were carrying out individual tasks in the chemistry laboratory, an exercise some form three students may not have been exposed to by the time of collecting this data. Quantitative data was collected from the whole sample while qualitative data was collected from participants drawn from the co-educational school. For the qualitative data, the participating school was a co-educational national school conveniently selected for its large population[2] of both male and female students who had already been exposed to the same context and as well taught by the same teacher(s) of chemistry.

Participants for the quantitative data were drawn from form three and four (ages 16-19 years). This was because the survey questions required participants to respond to questions on attitude and the ease of use of some selected instructional resources in the chemistry laboratory. The assumption was that the students had been exposed to those apparatus by the time of data collection. For the quantitative data, a further four schools were sampled and comprised of two girls' only and two boys' only schools. There were 4 unisex schools selected in and around Kiambu and Nairobi Counties and 1 co-educational school from Nakuru County and a teacher of chemistry from each school. In total there were 5 teachers and 145 student participants segregated into males (59) and females (86), left-handed (72) and right-handed (73).

[2] National co-educational secondary schools are known to have large student populations

INSTRUMENTATION AND DATA COLLECTION PROCEDURES

Both qualitative and quantitative data was collected for this mixed methods study. The quantitative data was collected by use of questionnaires in order to measure amounts of behavior, by assigning numeric values to what was being measured (the quantity). The qualitative data that usually results in descriptive data measured behavior (the quality) and was collected through a focus group discussion (FDG) with participants from the co-educational school. In total there were 12 participants for qualitative data (3 left-handed males, 3 right-handed males, 3 left-handed females and 3 right-handed females). Participants were coded L1, L2… L6 for the left-handed and R1, R2 … R6 for the right-handed.

Questionnaires

This self administered quantitative data tool was based upon validated open- and close-ended items, where rating scales and behavioral responses were collected. The questionnaires were given through hand delivery to the teachers of chemistry in the selected schools. The filled questionnaires were then collected one week later from the schools by the researcher. The participants in the qualitative research school filled the 20-25 minutes long questionnaire before the focus group discussion to void biases. The questionnaire was divided into four sections and had both open- and close-ended questions.

- Section one had 30 items each on attitudes and performance in chemistry. Each item was rated on a 5-point Likert type scale {from 1=strongly disagree (SA), 2=agree (A), 3=not sure (NS), 4=disagree (D) and 5=strongly agree (SD)}. Higher scores indicate higher positive attitudes towards chemistry.
- Section two had four items on completing timed tasks, attitudes and interaction with apparatus in the laboratory. Each item was rated on a 4-point Likert type scale (from

always, often, sometimes and rarely). The study participants were required to tick in the provided spaces then qualify their responses.

- Section three had 3 items each on experiences in the chemistry laboratory while section four had a list of commonly used (practiced) apparatus (activities) during practical sessions. The participants were required to rate them in terms of ease of use. The items had a 4-point Likert type scale (from very easy to use to very difficult to use). Participants were required to tick in the spaces provided then qualify their responses.

Focus Group Discussion Schedules

A focus group discussion with participants form the co-ed school to fill the gaps and points of concern form the survey was carried out. The researcher necessitated the identification of personal values, assumptions and biases at the outset of the study. The discussion guide included unstructured open-ended questions intended to elicit views and opinions on attitudes towards chemistry and effectiveness of learning institutions in meeting left-handers' needs, laboratory work. Participants also responded to questions on their experiences when undertaking timed tasks in chemistry. The responses were audio taped and notes taken.

Data Analysis Procedures

This procedure involved preparing collected data for analysis, moving deeper and deeper into understanding, representing and making sense of the data [57]. Quantitative and qualitative data were typically merged together in the interpretation stage in order to facilitate integrating them during analysis. The concurrent triangular design convergence model [61] was used to compare, validate, confirm and collaborate quantitative results and qualitative findings so as to end up with valid and well-substantiated conclusions about left-handers' attitudes towards chemistry [57]. The rationale for this approach was that it became easier for the researcher to qualify and compare quantitative data themes themes from the qualitative database [57].

Ethical Considerations

Confidentiality and anonymity of participants were offered prior to all data collection. However, teachers may be able to identify one another in the study and in some cases, the identity of the school may be apparent to readers in the local service. Furthermore, individual students who were interviewed were identified by their teachers, possibly introducing biased selection criteria of which the researcher would not be aware. It is difficult to assess whether students were willingly included or excluded in the study. Participating schools were informed of the aim of the research from the outset; investigation of the attitudes toward chemistry among left-handed high school students.

RESULTS AND DISCUSSION

This study sought to find out what effect the use of right handed instructional resources had on left-handers' attitude towards chemistry learning. There were 145 student participants and five teachers of chemistry from the five study schools.

The sample for this study was derived from a few schools (5), which may not be entirely representative of all schools in Kenya. Secondly, attitudes were not observed directly. Instead they were gathered as self-reports through the survey and the FGD with a small sample, which can lend itself to perceptional bias and possibly threaten, to some extent, the validity of the data. And lastly, the sample was unbalanced in terms of proportionality between sub-samples of left-handers, right-handers, males and females, which may have influenced, at some level, the response data gathered.

All the participants filled a self administered questionnaire that had items on perceptions towards chemistry learning. To triangulate the data further, an FDG was conducted with a mixed gender/handedness group. Collected data was broken into broad categories for analytical purposes. It was then prepared for analysis through coding. Editing and cleaning of collected data preceded analysis. Qualitative data was analyzed using descriptive statistics while quantitative data was analyzed using SPSS.

Students' Attitudes towards Chemistry

All participants in the study were enrolled in chemistry as an examinable subject by KNEC. While some students choose to drop chemistry after junior high school in Kenya, the researcher chose to find out the reasons these participants opted to take chemistry in senior high school. It emerged that subject choices were influenced by participants' parents/guardians and role models as well as science related future careers. Other students said that their decision to take chemistry was based on the subject being compulsory in their school, an indication that some students take chemistry to satisfy educational requirements.

Enrollment in chemistry is an indication that students were interested in the subject. According to Osborne, Simon and Collins [62], students' enrollment in the various scientific (non-compulsory) subjects suggested that the subject is a significant indicator of students' interest at the school level, especially in the post-compulsory phase of schooling. However, they pointed out that it would be erroneous to use enrollment as the sole measure of attitudes and interest in sciences. Regarding studying chemistry for future career and employment in sciences, research has failed to show a clear alignment between students' attitudes towards sciences and choosing future careers in sciences [63].

On another note, 3 out of 12 (25%) participants chose to pursue chemistry because of their teachers' influence on them. Participants described their teachers of chemistry as being cheerful, sympathetic, well prepared and passionate about chemistry. These teachers also varied their pedagogical approaches. Since teacher attributes were said to have enhanced students "liking" or "disliking" of chemistry, the teacher is therefore a factor in influencing student's attitudes towards chemistry. When students view a teacher as being motivated (de-motivated), there is a feeling that the teacher will most probably also motivate (de-motivate) learners in the subject. For example, one female left-handed participant, L3 said;

I chose to do chemistry and biology because the teacher was very motivated and possessed good teaching skills. The teacher of physics was quite tough so I disliked physics and dropped it after form two.

On varied pedagogical approaches, L5, a male left-handed participant claimed that chemistry practicals are interesting because …;

… it breaks the monotony of seeing teachers in front of you speaking all the time. It involves activities that make one actively involved in their own learning. It makes me understand better

Another 25% (3 out of 12) students also came out strongly against the subject. They had varying reasons for their attitudes. They expressed misgivings about some of their teachers. Such teachers were described as boring, rushing through their work and mostly not helping left-handers to cope with 'unfriendly' instructional resources. One left-handed male (L4) said;

Sometimes the teacher does not seem to know what they are talking about let alone knowing that I need help with fixing the burette and operating the three way pipette filler. I ask my friend to help me because he seems to understand me better

Research has shown that initial teacher training institutions do not train teachers on how to handle left-handed learners effectively in the classroom. This is because left-handedness has not been regarded as a special learning need in Kenya and elsewhere in the world [64]. However, it was established that out of their own volition, some teachers are warming up to the plight of left-handed students and are willing to give the attention and help these students require [12].

While students view teachers as playing pivotal roles in their choosing to take chemistry in senior high school, the aspect of future aspirations appeared to also influence subject choices and combinations. This is despite the curriculum and pedagogical approaches to teaching and learning of chemistry being important. It has been shown that students will choose to continue studying science if their teachers demonstrate personal interest in the students, support them and deliver the lesson with an encouraging attitude [11, 65, 66].

Findings showed a significant relationship between participants' handedness and their reasons for finding chemistry interesting (χ^2 =20.56, 6, p$\leq$ 0.05, two tailed). While students appreciate hands-on activities because they authenticate theory lessons [45], left-handers seemed to experience obstacles such as manipulating and handling selected instructional resources during the practical lessons compared to right-handers who comparably showed appreciation for accuracy in practical work. An equal number of left- and right-handers (12 each) said they found chemistry practicals interesting because it gave them an opportunity to be in charge of their own learning. There were more right-handers claiming that a mixture of theory lessons with practical sessions (57% of 23 participants), less obstacles experienced during task taking (59% of 17 participants) and accuracy in carrying out tasks and cognitive intelligence involved in doing mathematical calculations in chemistry was their main reasons for finding chemistry interesting (71% of 21 participants) (Table 1 below).

Findings revealed that most students felt practical work was not only exposing and preparing them for further chemistry but that it also accorded them opportunities to be in control of their learning. L3, a female left-handed participant said;

> *… chemistry practicals give one a sense of responsibility and maturity because when you are undertaking the task you have nobody else to look up to but yourself*

Out of the twelve participants who participated in the FGD, two (2) of them appreciated the importance of Chemistry for their future careers. They said that they liked the subject because of its practical nature. For example L5, a left-handed male participant said;

> *with practical work comes exposure to chemistry and this gives someone the syke (zeal) to continue further chemistry*

Interest in chemistry for future career was an encouraging revelation because Chemistry is increasingly becoming an opening to a number of key careers [67]. According to Fairbrother [68], students will learn only if there is a motivation to learn. When students are motivated by relevance and future careers in chemistry, they will approach the subject context with the right attitude. It has been opined by Simpson and Troost [69] that students would be more committed to science when they want to take more science courses and continue reading about science. Therefore, students who were of the view that chemistry syllabus was more “friendly” compared to other sciences would be more committed to the subject.

Table 1: Participants' handedness and why chemistry practicals are interesting

Participant's active hand		**Reason why chemistry practical lessons are interesting**							
		Active participation than in theory	Mixture of theory with practical lessons	Fewer obstacles experienced	Based on accuracy & intelligence	N/A	Did not answer	Other	Total
Right	**Frequency**	**12**	**13**	**10**	**15**	**19**	**0**	**4**	**73**
	% within participant's active hand	16%	18%	14%	21%	26%	0%	6%	100%
	% within reason why chemistry practical lessons are interesting	50%	57%	59%	71%	59%	0%	17%	50%
Left	**Frequency**	**12**	**10**	**7**	**6**	**13**	**4**	**20**	**72**
	% within participant's active hand	17%	14%	10%	8%	18%	6%	28%	100%
	% within reason why chemistry practical lessons are interesting	50%	44%	41%	29%	41%	100%	83%	50%
Total	**Frequency**	**24**	**23**	**17**	**21**	**32**	4	**24**	**145**
	% within participant's active hand	17%	16%	12%	15%	22%	3%	7%	100%
	% within reason why chemistry practical lessons are interesting	100%	100%	100%	100%	100%	100%	100%	100%

Eight of twelve participants (75%) claimed that chemistry syllabus was "friendlier" compared to that of both Biology and Physics. The reasons given ranged from the relationship between chemistry and these other science subjects, the syllabus generally and specifically the way the topics are arranged as well as the relationship between themes in the topics across the subjects. One female left-handed participant (L2) said;

> *Chemistry is related to all other sciences (biology, physics, mathematics) hence easy to manage (understand)*

While a left-handed male (L6) claimed;

> ***….**chemistry ni kujirudiarudia (pause)….. The same concepts we started with in form one keep growing in depth and width as one approaches fourth form therefore making it less complex*

L5, a male left-handed participant argued that;

> *…..the chemistry syllabus is less and (it is) more manageable because it grows in a repetitive and spiral way. The relationships in the topics are also more pronounced compared to those in (pause) for example biology where one day you are learning something in animals and the other day you are doing something in plants and the whole thing is quite confusing to me*

The chemistry syllabus being repetitive in a spiral way means students are able to easily make connections between the concepts more meaningfully and deeply [6]. As the concepts make more sense, chemistry becomes more relevant and meaningful to the students. When students feel that they are familiar with concepts from their previous studies, and feel confident enough to explain them, it positively affects their motivation and achievements and therefore they develop the right attitudes towards learning the subject.

A significant relationship was found between handedness and chemistry being difficult and time consuming (χ^2 =13.38, 4, p$\leq$ 0.05, two tailed). Out of 145 participants, 27 (19%) of them strongly agreed that chemistry was difficult and time consuming. Twenty two (82%) of these participants were right handed and the rest (5) were left-handed (Table 2). An almost equal number (49% right-handed and 51% left-handed) of participants disagreed that chemistry was difficult and time consuming while slightly more left-handers than right-handers strongly disagreed that chemistry was difficult and time consuming (59% and 41% respectively).

Table 2: Participants' handedness and whether chemistry is difficult compared to other sciences

Participant's active hand		Chemistry is more difficult and time consuming compared to other sciences					
		SA	**A**	**NS**	**D**	**SD**	**Total**
Right	**Frequency**	**22**	**9**	**7**	**16**	**19**	**73**
	% within participant's active hand	30%	12%	10%	22%	26%	100%
	% within chemistry is more difficult & time consuming compared to other sciences	82%	41%	41%	49%	41%	50%
Left	**Frequency**	**5**	**13**	**10**	**17**	**27**	**72**
	% within participant's active hand	7%	18%	14%	24%	38%	100%
	% within chemistry is more difficult & time consuming compared to other sciences	19%	59%	59%	52%	59%	50%
Total	**Frequency**	**27**	**22**	**17**	**33**	**46**	**145**
	% within participant's active hand	19%	15%	12%	23%	32%	100%
	% within chemistry is more difficult & time consuming compared to other sciences	100%	100%	100%	100%	100%	100%

In addition, there was a significant relationship between participants' sex and the perception of chemistry being difficult and time consuming (χ^2 =9.95, df4, $p \leq 0.05$, two tailed). Out of 86 female participants in the sample, 27 (31%) of them and 22 (37%) out of 59 male participants in the study sample agreed that chemistry was more difficult and time consuming compared to other science subjects. Forty six out of 86 (53%) females compared to 33 out of 59 (56%) males disagreed that chemistry was difficult and time consuming.

About 68% (8 out of 12) of those participants who were interviewed said they found chemistry interesting to learn. The rest (4 out of 12) felt that it was a difficult and time consuming subject. Chemistry being a difficult and time consuming subject was attributed to the content of the subject, the language used and the structure of questions in the assessment of chemistry. One male participant (L4) on the structure of the questions said;

> *Some of the apparatus are not easier to use as well as the mole concept questions after the questions. ….., the mole concept,…. it gets confusing when the calculations which you think are right end up being wrong*

A female participant L3, on the language of chemistry said;

> *How the examinations are set, it is too complicated and sometimes I fail not because I did not know but because of not using the language of chemistry in answering the exam questions*

While L1, a male participant cited the task context as a challenge by saying;

> *Sometimes I find it hard to coordinate with all the apparatus that need to be used. Some questions also need a lot of ……, (pause) …., a lot of ……, there is just too much multitasking like in salts, checking the crystal formation, stopping the stopwatch, reading the thermometer and recording all at the same time??*

Findings indicated that the reasons for finding chemistry challenging revolved around the subject and the pedagogical approaches teachers used to present content in the classroom. The language in chemistry played a major role with students complaining that they sometimes failed in their examinations because they did not use the right language.

The language of chemistry is one that needs teachers to explain the meaning of the words as used in a chemistry context as opposed to their use in everyday life. It has been suggested by

Gilbert [70] that teachers could select those parts of 'chemical language' that are needed for students to grasp the meaning of the chemistry involved in their learning.

Right-handers compared to left-handers felt that chemistry was difficult and time consuming; 53% and 20% respectively. Females more than males also felt that chemistry was more difficult and time consuming. When chemistry is viewed by learners as difficult to understand and time consuming, this is an indication that there is lack of confidence by the students in the subject. The difficulties experienced in grasping the concepts and feelings that chemistry takes students' time erodes the confidence that they might have in the subject. Since students fail to make connections between the different facts and concepts presented together with their practical applications, the students miss the 'big picture' of science and never develop confidence in its relevance. Clearly, all these have potential to influence attitudes and interests.

It has been postulated by Hofstein and Mamlok-Naaman, [6] that relevance, attitudes and interest in the subject are related, that is, if students find the science (in this case chemistry) content that they learn relevant to their daily life and to the society in which they operate, there is a good chance that they will develop positive attitudes towards the subject.

Students Self-Efficacy in Chemistry

Asked to rate their feelings about chemistry tests, there was a significant relationship between handedness of students in the study and feelings of nervousness during chemistry tests (χ^2 =12.872, 4, $p \leq 0.05$, two tailed). About 60% of the 145 participants agreed that chemistry tests made them nervous. About 76% (22 out of 29) of those who strongly agreed that chemistry tests made them nervous were right-handed while 61% (14 out of 23) of those who strongly disagreed that chemistry tests made them nervous were left-handed. Further and contrary to the right-handed students who are mostly made nervous by chemistry tests, 68% (21 out of 31) left-handers disagreed that chemistry tests make them nervous (Table 3).

Table 3: Participants' handedness and participants' feelings about chemistry tests

Participant's active hand		Chemistry test makes the student nervous					
		SA	**A**	**NS**	**D**	**SD**	**Total**
Right	**Frequency**	**22**	**27**	**5**	**10**	**9**	**73**
	% within participant's active hand	30%	37%	7%	14%	12%	100%
	% within chemistry test makes me nervous	76%	51%	56%	32%	39%	50%
Left	**Frequency**	**7**	**26**	**4**	**21**	**14**	**72**
	% within participant's active hand	10%	36%	6%	29%	19%	100%
	% within chemistry test makes me nervous	24%	49%	44%	68%	61%	50%
Total	**Frequency**	**29**	**53**	**9**	**31**	**23**	**145**
	% within participant's active hand	20%	37%	6%	21%	16%	100%
	% within chemistry test makes me nervous	100%	100%	100%	100%	100%	100%

Nervousness during examinations may have contributed to over 60% of the 145 students who participated in this study either disagreeing or strongly disagreeing that given an opportunity they would refrain from taking chemistry in school signifying that, although majority of the participants in this study find chemistry interesting and as an important science subject, there were challenges that hindered their optimum appreciation and performance in the subject.

During the FGD, participants expressed concern that although chemistry was a more manageable science compared to other elective sciences, left-handers felt that they had to put in more work compared to their right-handed peers. One of them said;

> *I strongly feel I have to work harder than my right-handed colleagues because I have to take more time 'getting around the environment' yet I have to perform well in my exams. The school does not help to ease the situation in any way (L6)*

In terms of the relationship between handedness and participants' responses on whether they would take chemistry again given another opportunity, a significant relationship existed (χ^2 =9.82, 4, p≤ 0.05, two tailed). Out of the total 18 participants who strongly agreed that they would not take chemistry again given another opportunity, 15 (83%) of them were right-handed (Table 4). This finding signifies that left-handed students, indeed, value their time investment in pursuing chemistry in school.

Table 4: Participants' handedness and whether they would choose take chemistry again if they were given another opportunity

Participant's active hand		**Given a choice, I would not choose to do chemistry again**					
		SA	**A**	**NS**	**D**	**SD**	**Total**
Right	**Frequency**	**15**	**9**	**6**	**14**	**29**	**73**
	% within participant's active hand	21%	12%	8%	19%	40%	100%
	% within given a choice, I would not take chemistry again	83%	41%	40%	44%	50%	50%
Left	**Frequency**	**3**	**13**	**9**	**18**	**29**	**72**
	% within participant's active hand	4%	18%	13%	25%	40%	100%
	% within given a choice, I would not take chemistry again	17%	59%	60%	56%	50%	50%
Total	**Frequency**	**18**	**22**	**15**	**32**	**58**	**145**
	% within participant's active hand	12%	15%	10%	22%	40%	100%
	% within given a choice, I would not take chemistry again	100%	100%	100%	100%	100%	100%

About 91% (78 out of 86) females compared to 83% (49 out of 59) males said they found chemistry practicals interesting while 58% (50 out of 86) females compared to 54% (32 out of 59) males claimed that chemistry tests made them nervous. On whether participants thought chemistry was relevant and useful in their future life, more females than males agreed (59% and 44% respectively) that chemistry would be useful for their future.

Findings seem to suggest that left-handed participants in this study had decided to pursue their decision of taking chemistry as an optional subject in senior high school. Despite the challenges experienced in the laboratory while manipulating right handed instructional resources, left-handers appeared more interested in understanding the scientific concepts, and therefore will exhibited more positive attitudes towards science and science studies despite experiencing learning difficulties in the chemistry laboratory. It can therefore be concluded that the challenges left-handed students experience in the chemistry laboratory do not cause them to harbor negative attitudes towards chemistry learning.

Aspirations for Further Chemistry

A significant relationship was found between participants' handedness and their plans not to continue with chemistry after school (χ^2 =11.70, 4, p≤ 0.05, two tailed). Fewer right-handers 42% (31 out of 73) compared to left-handers 39% (28 out of 74) said they would continue with chemistry after high school. Comparably too, there were fewer left-handers 32% (23 out of 72) compared to 45% (33 out of 73) right-handers who agreed that they would not continue with further chemistry after school. On the contrary 70% of the participants who were not sure of their plans to continue with chemistry after high school were left-handed (Table 5).

Table 5: Participants' handedness and their uptake on Chemistry after high school

Participant's active hand		**No plan to continue with chemistry after high school**					
		SA	**A**	**NS**	**D**	**SD**	**Total**
Right	**Frequency**	**24**	**7**	**9**	**15**	**18**	**73**
	% within participant's active hand	33%	10%	12%	21%	25%	100%
	% within no plan to continue with chemistry after high school	62%	35%	30%	68%	53%	50%
Left	**Frequency**	**15**	**13**	**21**	**7**	**16**	**72**
	% within participant's active hand	21%	18%	29%	10%	22%	100%
	% within no plan to continue with chemistry after high school	39%	65%	70%	32%	47%	50%
Total	**Frequency**	**39**	**20**	**30**	**22**	**34**	**145**
	% within participant's active hand	27%	14%	21%	15%	23%	100%
	% within no plan to continue with chemistry after high school	100%	100%	100%	100%	100%	100%

Focus group discussions revealed that some of the reasons that participants were against taking further chemistry indicated that continuing with further chemistry was pegged on whether they would make it in the final examination. One female participant L2 said;

I can only continue with chemistry depending on my performance after fourth form. If it is favorable then I will

Although left-handers were facing difficulties manipulating instructional resources in the laboratory, there was a mutual feeling that given more time and a fair operating context, they would do much better in their achievement. This was because the time allocated was not enough to do the adjustments with the apparatus and still manage to meet the task requirements on time. The use of mismatched desks, hooking hands wrongly while writing thereby making left-handers get more tired and coping with 'ungraspable' instructional resources are some of the reasons that made left-handed participants request for extra time during practical examinations. On the time allocated to practical work participants said;

> Too much writing makes me tired and uncomfortable. I prefer we were given more time and our work stations arranged with 'us' in mind (L3)

> Examinations that require a lot of writing take up too much time and most of the times I do not complete them. The shifting of apparatus during a practical session eats into the task time (L1)

> I get very tired during exams and more so chemistry 233/2. I do not always finish timed exams because some questions require a lot of writing. However, am okay with short answer questions. I find chemistry paper three (233/3) uncomfortable during the session because some of the apparatus give me a hard time (L5)

> Some exams come out badly because of the confusion that comes with using apparatus that feel wrong to work with (L2)

The most effective factor contributing to students' decisions to study science is their interest in the subject [47]. Left-handed students in this study would not only choose to take high school chemistry again given another opportunity but they were also determined to continue with chemistry after school. This signifies that they had the right attitude toward the subject because they found it relevant. Compared to their right-handed peers, left-handers experienced challenges while using some selected instructional resources in the laboratory. However, this did not deter them from pursuing their dreams of continuing further chemistry and science related careers. Comparably therefore, left-handers are more interested in chemistry than their right-handed peers. This is because as earlier found, many right-handers had said that they took chemistry because their parents wanted them to pursue science related careers while others said that they took chemistry because it was compulsory in their school.

As has been suggested by Gilbert [70], many students who choose to study chemistry to satisfy requirement experience lack of relevance in it and seem to view it in an instrumental way, rather than because it is worthwhile in itself. Considering that discomfort during chemistry laboratory activities is a state occurring in response to situations concerning chemistry tasks which can often create a negative attitude toward the subject [71], the relationships between discomfort in the chemistry laboratory and chemistry attitudes are easily understandable. That is negative attitudes towards chemistry are promoted while positive attitudes are decreased by discomfort during chemistry laboratory practicals. However, did not seem applicable to the left-handers in this study.

Although left-handers experience more than their share of challenges during chemistry practicals, they seemed positive towards the subject as opposed to right-handers whom majority were categorical that they would not take chemistry after senior school. This assertion is in agreement with Salta and Tzougraki [13] that although students believed that the chemistry course was not useful for their future career, they recognized the importance of chemistry in their life. Chemistry attitudes are important factors highly associated with chemistry success and motivation. Students with positive attitudes towards chemistry are more likely to sustain their efforts and have the desire to be involved in learning tasks [21].

CONCLUSION AND RECOMMENDATIONS

This paper has revealed that left-handers harbor more positive attitudes towards chemistry compared to right-handers. Further, female participants appear to have somewhat more positive attitudes towards chemistry compared to males. Students' lack of interest in chemistry and low self-efficacy during practical work are contributing factors. From the study, it was apparent that certain content-related pedagogical approaches are more effective than others. More attention should be drawn to the learning context and more specifically the laboratory environment. Based on the study findings, it is clear that girls (as opposed to boys) prefer a more cooperative learning environment as opposed to whole-class learning [72].

Future development in chemistry teaching and learning should pay more attention to mismatches that arise in the classroom, different students' gender, motivational patterns, and learning styles [73]. This is in fact a call to vary the chemistry classroom learning environment so that it will cater for all learners [74]. Mismatches in the classroom are some of the reasons left-handed learners are unable to reach their threshold during performance of hands-on, minds-on activities. The researcher suggests that chemistry curriculum developers and instructors to factor in the peculiar physiological differences in the case of left-handers, for example allowing more time to make adjustments that would make them comfortable during timed tasks would go a long way in assisting them achieve their learning goals more effectively.

Here the study has examined several areas that can potentially enhance learning science in general and chemistry in particular for left-handed learners. However, there is not a crystal clear picture that informs teachers on how attitudes influence motivation and how motivation influences the learning of chemistry for this particular group of learners [75]. More research is needed in order to advance knowledge regarding attitudes that may have been accumulated thus far.

REFERENCES

1. Smith, M. C., Walker, D. A., & Hamidova, N. (2011). Distinguishing students' attitudes towards science from their beliefs about science: does it matter? Paper presented at the biannual meeting of the 2010 northern region adult education fall conference, Bloomington, II
2. Sarnoff, I. (1960). Psychoanalytic theory and social attitudes. Public opinion quarterly, 24, 251-279
3. Shringley, R. L. (1983). The attitude concept and science teaching: *Journal science education-SCI EDUC,* 67(*4*), 425-442

4. Gardner, P. L. (1975a). Attitudes to science: a review. *Studies in science education*, 2, 1-41
5. Schibeci, R. A. (1983). Selecting appropriate attitudinal objectives for school science. *Science education*, 67, 595-603.
6. Hofstein, A. & Mamlok-Naaman, R. (2011). High-School Students' Attitudes toward and Interest in Learning Chemistry 2011 international year of chemistry [attitude toward chemistry] Educ. 22(*2*), 90-102,
7. Giallo, R. & Little, E. (2003). Classroom Behavior Problems: The Relationship between Preparedness, Classroom Experiences, and Self-efficacy in Graduate and Student Teachers. *Australian Journal of Educational & Developmental Psychology*. 3, 21-34. Retrieved from http://www.newcastle.edu.au/journal/ajedp/ in July 2014.
8. Keeves, J. P., & Morgenstern, C. (1992). Attitudes toward science: Measures and effects. In J.P. Keeves (Ed.) The IEA Study of Science III: Changes in science Education and Achievement: 1970-1984 (pp. 122-140). New York: Pergamon.
9. Deboer, G. E. (1987). Predicting continued participation in college Chemistry for men and women. Journal of research in science Teaching, 24(*6*): 52-238.
10. Mwamwendwa, T. S. (1995). Educational Psychology. An African Perspective. London: Heinemann Butterworth Publisher Ltd.
11. Fraser, C. (1994). Attitudes, social representations and widespread beliefs. Papers on social representations 3(*1*), 1-133. University of Cambridge, Great Britain,
12. Malusi, B. M. (2014). Challenges left-handed students face in Kenyan High School Science Laboratories: *African Journal for Research in Chemistry Education*, 4(*3*), 50-81, Special Issue (Part II).
13. Salta, K. & Tzougraki, C. (2004). Attitudes Toward Chemistry Among 11th Grade Students in High Schools in Greece Wiley InterScience (www.interscience.wiley.com) 535-547.
14. Barmao, P. K. (2013). Differences in performance between boys and girls in secondary school science subjects in Keiyo district, Kenya International Journal of Advanced Research 1(*5*), 449-454
15. Linn, M. C. (1992). Science Education reform: Building the research base. *Journal of Research in Science Teaching*, 29, 821-840
16. Hofstein, A., Ben-zvi, R., Samuel, D., & Tamir, P. (1977). Attitudes of Israeli high-school students toward chemistry and physics: A comparative study. *Science Education*, 61(*2*), 259-268.
17. Kan, A., & Akbaş, A. (2006) Affective Factors that Influence Chemistry Achievement (Attitude and Self Efficacy) and the Power of these Factors to Predict Chemistry Achievement-I. *Journal of Turkish Science Education*, 3, 1.
18. Inye, H. H. (2011). Attitudes of Students towards Science and Science Education in Nigeria. (A Case Study in Selected Secondary Schools in Obio/Akpor Local Government Area of Rivers State). *Continental J. Education Research*, 4(2), 33-51.
19. Belge-Can, H. (2012). A Cross-Age Study on High School Students' Attitudes towards chemistry. International journal on new trends in education and their implications, 3(*3*), 82-9. Retrieved July 2013.
20. Lim, D. H. & Morris, M. L. (2009). Learner and Instructional Factors Influencing Learning Outcomes within a Blended Learning Environment. *Educational Technology and Society*, 12(*4*), 282-293. Accessed September 2013 from www.iftes.info/journals/12_4/24.pdf.

21. Kurbanoglu, N., & Akim, A. (2010). The Relationships between University Students' Chemistry Laboratory Anxiety, Attitudes, and Self-Efficacy Beliefs, *Australian Journal of Teacher Education*, 35(*8*), 47-59. Retrieved September 2013 from http://ro.ecu.edu.au/ajte/vol35/iss8/4.
22. Schwartz-Bloom, R. D., Halpin, M. J. & Reiter, J. P. (2011). Teaching High School Chemistry in the Context of Pharmacology Helps Both Teachers and Students Learn. *Journal of chemical education*, 88, 744–750. Accessed August 2013 from dx.doi.org/10.1021/ed100097y.
23. Millar, R. (2008). Taking scientific literacy seriously as a curriculum aim. Asia-Pacific Forum on Science Learning and Teaching, 9(*2*), 1-18.
24. Karanja, D. (2004). Kenya takes steps to develop women Scientist. Retrieved in May 2014 from http/www.women.news.org/archieve.cfm.htm
25. Inzahuli, S. M., Elizabeth, R. &, Lazarus, N. M. (2012). Gender Disparities in Self-efficacy, Attitude and Perception in Physics and Chemistry. *Atlas Journal of Science Education*, 2(*1*), 61-69. Retrieved from doi: 10.5147/ajse.2012.0097 in January 2015
26. Cheung, D. (2007). Students' Attitudes toward Chemistry Lessons: The Interaction Effect between Grade Level and Gender: Res Sci Educ 39: 75–91 doi 10.1007/s11165-007-9075-4.
27. Shannon, A. G., Sleet, R. J., & Stem, W. (1982). School students attitudes to science subjects. *Australian Science Teachers' Journal*, 28(*1*), 77-82
28. Menis, J. (1983). Attitudes towards chemistry as compare with those towards mathematics, among tenth grade pupils (aged 15) in high level secondary schools in Israel. *Research in Science and Technological Education*, 1(*2*), 185–191.
29. Harvey, T. J., & Stables, A. (1986). Gender differences in attitudes to science for 3rd year pupils: An argument for single sex teaching groups in mixed schools, *Research in Science and Technological Education*, 4(*2*), 163-170.
30. Barnes, G., McInernery, D. M., & Mash, H. W. (2005). Exploring sex differences in science enrollment intentions: An application of the general model of academic choice. Australian educational researcher, 32(*2*), 1-23
31. Cheung, D. (2009). Students' attitudes toward chemistry lessons: The interaction effect between grade level and gender. *Research in Science Education*, 39, 75-91.
32. Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive Science, 12, 257–285.
33. Miller, G. A. (1956). The magical number seven, ± two: Some limits on our capacity for processing information. *Psychological Review*, 63, 81–97.
34. Atkinson, R. C. & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. Spence and J. Spence (Eds.), The psychology of learning and motivation, 2, 89-195. New York: Academic Press.
35. Baddeley, (1992). Working memory Science, 255, 556-559. Retrieved from www.ebookee.com.
36. Eraut, M. (1994). Developing professional knowledge and competence. London: The Falmer Press.
37. Sweller, J., van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, 10, 251-296.

38. Bargh, J. A. (1999). The cognitive monster. The case against the controllability of automatic stereotype effects. In S Chaiken & Y Trope (Eds), Dual-process theories in social psychology. (pp.361-382). New York; Guilford press
39. Convention on the Rights of the Child: Adopted and opened for signature, ratification and accession by General Assembly resolution 44/25 of 20 November 1989 entry into force 2 September 1990, in accordance with article 49. Accessed Nov 2012.
40. Hofstein, A., & Lunetta,V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research, *Review of Educational Research*, 52(2), 201-217,
41. Tobin, K. G. (1990). Research on science laboratory activities; In pursuit of better questions and answers to improve learning, School Science and Mathematics, 90, 403-418,
42. Lunetta, V. N. (1998). The school science laboratory: Historical perspectives and context for contemporary teaching. In B. Fraser & K. G. Tobin. (Eds.), *International handbook of science education* (pp. 249-262). Dodrecht, The Netherlands: Kluwer.
43. Hofstein, A. & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century: Department of Science Teaching, *The Weizmann Institute of Science, Rehovot76100, Israel Science Education*, The Pennsylvania State University: University Park.
44. Lunetta, V. N., Hofstein, A., & Clough, M. (2007). Learning and Teaching in the School Science Laboratory: An analysis of research, theory, and practice. In: S. Abell., & N. Lederman (Eds.). *Handbook of Research on Science Education*. Mahwah, New Jersey: LEA Publishers,
45. Ben-Zvi, R., Hofstein, A., Samuel, D., & Kempa, R. F. (1976).The attitude of high school students to the use of filmed experiments, *Journal of Chemical Education*, 53, 575-577,
46. Okebukola, P. A. (1986). An investigation of some factors affecting students' attitude toward laboratory chemistry, *Journal of Chemistry Education*, 63, 531-532.
47. Milner, N., Ben-Zvi, R., & Hofstein, A. (1987). Variables that affect students' enrollment in science courses, *Research in Science and Technological Education*, 5, 201-208.
48. Rueckert, L & Brinkman, D. (2001). Bimanual coordination deficits in left-handers. A paper presented at the annual meeting of the Cognitive Neuroscience Society, New York, NY. Retrieved July 2013.
49. Parish, A. (2011). Effect of handedness on gross motor skill acquisition among college undergraduates. Retrieved July 2013.
50. Silverman, S. (2009). Stance for Left-handed Golfers. Retrieved on 15-June-2013 from: www.golflink.com./how_317_stance-lefthanded-golfres.html.
51. Rouet, J.-F. (2009). Managing cognitive load during document-based learning. Learning and Instruction. Retrieved May 2014.
52. Pollock, E., Chandler, P. & Sweller, J. (2002). Assimilating complex information Learning and Instruction 1261–1286 University of New South Wales, Sydney 2052, New South Wales, Australia. Retrieved from www.elsevier.com/locate/learninstruc.
53. Dhara, P. C., Khaspuri, G. & Sau, S. K. (2008). Complaints arising from a mismatch between school furniture and anthropometric measurements of rural secondary school children during class work:www.ncbi.nlm.nih.gov in August 2013.Gabel, D. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future. Journal of Chemical Education, 76(*4*), 548-554.
55. Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, 7, 75-83.

56. Bishop, D. V. M. (1990). *Handedness and Developmental Disorder*. Lawrence Erlbaum Associate Publishers: Hove, UK.
57. Creswell, J. W. (2003). Research design. Sage publication. Accessed in September 2013.
58. Lincon, Y. S & Guba, EG (2000). Paradigmatic controversies, contradictions and emerging influences. In N. K. Denzin & Y. S. Lincon (Eds.), the handbook of qualitative research (2nd edn) (pp. 163-188). London: sage
59. Bamberger, M. (2012). Introduction to Mixed Methods in Impact Evaluation: *Impact Evaluation Notes*. Retrieved September 2013 from http://www. interaction.org/impact-evaluation-notes.
60. Lor, P. (2011). International and Comparative Librarianship, *Chapter 4 draft*. Retrieved September, 2013.
61. Creswell, J. W. (2006). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, Second Edition. Accessed October, 2013
62. Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. International Journal of Science Education, 25(*9*), 1049–1079.
63. Shringley, R. L. (1990). Attitude and behavior correlates, *Journal of Research in Science Teaching*, 27, 97-113,
64. Milsom, L. (1995). Left-handed children are they losing out? *Educational media international,* 32, 107-108.
65. Lee, V. E. & Burkham, D. T., (1996). Gender differences in middle grade science achievement: subject domain, ability level and course emphasis. *Science and Education*, 80(*6*), 613-650
66. Shringley, R. L., Koballa, T., & Simpson, R. (1988). Defining attitude for science educators. *Journal of research in science teaching*, 25(*8*), 659-678
67. Chepkorir, S. (2013). The Impact of Students' Attitudes on the Teaching and Learning of Chemistry in Secondary Schools in Bureti District, Kenya: *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS)* 4(*4*): 618-626. Retrieved in August 2014 from www.scholarlinkresearch.org
68. Fairbrother, R.W. (2000). Strategies for learning. In: M. Monk & J. Osborne (Eds.), *Good practice in science teaching* (pp. 7-24). Philadelphia: Open University.
69. Simpson, R. D., & Troost, K. M. (1982). Influences on commitment to and learning of science among adolescent students, *Science Education*, 66(*5*), 763-781.
70. Gilbert, J. K. (2006). On the nature of context in chemical education. *International Journal of Science Education*, 28(*9*), 957-976
71. Eddy, R. M. (2000). Chemophobia in the college classroom: Extent, sources, and students characteristics. Journal of Chemical Education, 77(*4*), 514–517.
72. Zohar, A., & Sela, D. (2003). Her physics, his physics: gender issues in Israeli advanced placement physics classes, *International Journal of Science Education*, 25, 245-268,
73. Hofstein, A., & Kempa, R. F. (1985). Motivating aspects in science education: An attempt at an analysis. *European Journal of Science Education*, 7, 221–229.
74. Hofstein, A., & Walberg, H. J. (1995). Instructional strategies. In B. J. Fraser & H. J. Walberg (Eds.), improving science education (pp. 70-89). Chicago: National Society for the Study of Education.
75. Koballa, T. R., & Glynn, S. M. (2007). Attitudinal and Motivational Constructs in Science Learning. In: S. Abell, & N. Lederman (Eds.). *Handbook of Research on Science Education* (pp. 75-102), Mahwah, New Jersey: LEA Publishers.