Effect of Handedness on Completion Rate of Chemistry Timed Tasks by Left-Handed Learners

Benerdeta Malusi, University of Nairobi, Kenya
Odiemo L.O, University of Nairobi, Kenya

Abstract
Handedness has been shown to affect left-handed learners' performance generally and specifically during practical work in chemistry. This is because left-handers experience learning difficulties associated with handling and manipulating right-handed resources. The purpose of this study was to investigate whether left-handed learners' use of right-handed resources has any effect on their completion rate and performance in chemistry. Data was collected from left- and right-handed students of chemistry from a co-educational secondary school in Kenya during practical work. Data showed no statistical significance difference between on- and off-task time by the participants. However, left-handers have to not only work a little bit faster, they also have to put in more effort and time in order to complete timed chemistry tasks. An independent t-test showed no significant differences between left- and right-handers' task scores. These findings helped demonstrate that the use of right-handed instructional resources by left-handers may have an undesirable effect specifically on completion rate of timed chemistry tasks and performance. Therefore, for inclusivity, left-handedness has to be treated as a special learning need. Due to the small number of participants, it was suggested that in order to increase construct and concurrent validity, time-on-task samples from a larger participant group across grades should be obtained. It was further suggested that in order to alleviate the negative effects of switches, teachers should be knowledgeable of strategies to maintain on-task behavior, meaning that learners with the same challenges need to be put together so that they all transit together during learning.

Keywords*:* performance, timed tasks, on-task, off-task, task completion rate, left-handers, right-handers

iafor

The International Academic Forum
www.iafor.org

BACKGROUND INFORMATION

Introduction

The crucial objective of any schooling program is to offer all learners a safe and appealing environment, coupled with sufficient opportunities to learn (Martinez & Brock, 2009). To achieve this, a large portion of a student's typical school day has to be allocated towards providing these opportunities. However, allocation of learning opportunities is not the only recipe for good performance. Handedness has been shown to affect students learning generally and specifically during engaged time. It is on this premise that this study is based, to establish whether a mismatch between handedness and the design of instructional resources influences left-handers' task completion rate and performance in school chemistry.

Slavin (2003) defines time on-task (engaged time) as the amount of time spent learning. It is more than a behavioral concept because it also encompasses the emotional commitment to academics (Weghe, 2006). This is because it is the most important influence on academic achievement (Greenwood, Horton & Utley, 2002; Slavin, 2003). Consequently, classroom activities that appropriately and effectively engage learners are also geared towards achieving a favorable learning environment.
Despite earning its place in the world of science, chemistry is pivotal in the learning of other sciences. This is partly because chemistry learning develops transferable scientific work habits in students (Hibbard, et. al, 2015). In this regard and the fact that teachers may not be privileged to dictate the nature of students who join their classrooms, the facet of handedness can neither be ignored nor wished away, based on the fact that 10% of any randomly sampled population comprises left-handed persons (Bishop, 1990).

The relative importance of chemistry to the unfolding world notwithstanding, the performance of Kenyan students in chemistry at the secondary school remains a dismal failure in examinations (Otieno, 2013). Many factors have been cited to contribute to this poor performance, vis-à-vis student factors, teacher factors, parental influence and cultural beliefs (Muya, 2000), teachers' qualification, efficiency of teaching and learning methodology used (Mahajan & Singh, 2005) and science teachers' classroom management effectiveness (Orji, 2014; Tunde, 2014). The context and the resources available and their influence on a learner's cognitive load (Rouet, 2006) have also been reported as being significant.

Handedness has also been shown to affect learner performance (Malusi, 2014; Parish, 2011; Kula, 2008). This is because in the learning environment, left-handers experience learning difficulties (Kula 2008; Johnston, Shah & Shields, 2007) brought about by not only the settings in these contexts but also the activities therein. For example, the act of writing left to right has been shown to present a special obstruction for left-handers (Lance, 2005) since they have to bend over their work in order to see what they are writing; an exercise that usually leads to possible back, neck, shoulder and hand aches. As far as performance in school subjects is concerned, in one school in England, Williams (1987) found that left-handed children generally performed less well in French, Science and History compared to right-handed children. However, Annett and Manning (1989) found contrasting findings. Using a sample of 175 boys and 173 girls from six schools in central England, they

established that right-handed children performed poorer in Matrices and English compared to left-handed children.

A review by Johnston, Nicholls, Shah and Shields (2009) broadly divides the various theories on the origins of handedness into: genetic explanation, exogenous factors and the social environment. Whatever the cause, left-handedness affects learners in the classrooms because the world is made up-down by the right-handed for the right-handed (Silverman, 2009). Experimentally, 50% of all three-year-olds show a clear preference for using either the right or the left hand, a percentage that rises to about 90 in favor of the right hand by the time children start formal school (Bishop, 1990). Remarkably, most researchers working with children are interested in the development of hand preferences because of both its impact on hand skill and the possible relationship to brain function (Kula, 2008).

Attention to external sources of information by learners is guided by their understanding of the task context, for instance, mental representation of the requirement by the problem statement and the perception of realistic constraints of the situation such as time availability and learning benefits (Björklund, 2013). Rouet (2006) opines that the set of tools and information resources available in the environment which sometimes include resources to facilitate the means to the end present are another source of cognitive load. Rouet further argues that prior knowledge, learners' physiology, more general cognitive abilities and level of expertise help shape the individual characteristics of learners. Ultimately, it appears that effective learning results from the interplay between these aspects and a mismatch between any of them may cause challenges during learning. For example, a mismatch between learning resources and leaner physiology can artificially increase extrinsic load because the learner may have to put in more effort and time thinking of the how and the when to reverse instructions (Silverman, 2009) so as to effectively respond to the task requirements.

This study is premised on the assumption that many instructors and the left-handers themselves do not realize that the correct learning resources would improve performance. Generally, practical subjects in school, such as practical arts, home economics, woodwork and metalwork (which involve using heavy machinery) as well as the sciences have raised concerns, both with blade positioning and over the positioning of safety overrides, which are positioned for right-handers' convenience. This means that left-handers can lose valuable seconds in an emergency, as they would instinctively reach out with their dominant hand in moments of stress.

Statement of the problem

Learning and examination contexts are set for right-handers and instructions are also given in their favor. In chemistry laboratory learning and assessment, it is expected that a learner should have automated the necessary skills for manipulating learning resources thereby dedicating most of the conscious cognitive information processing efforts to the learning content. However, for left-handers who have to manipulate equipment designed for right-handers, the balance between the conscious and unconscious information processing is somewhat disturbed. This leads to a situation where left-handers are forced to not only consciously focus on on-task activities, but also active off-task activities, for example, the manipulation of learning resources for

the task. The need to consciously pay attention to manipulating these resources constitutes extrinsic cognitive load which has been found to negatively influence task performance. In the case of timed tasks or the need to apply knowledge in new contexts, left-handers will most likely be disadvantaged because they have to deal with and process more information during the allocated time. The learner will most likely have to put in extra effort and time at processing information as well as trying to fit and comfortably remain on-task in an 'unfamiliar' environment. On this backdrop, this study is based; to establish whether a mismatch between handedness and learning resources design influences left-handers' task completion rate and performance in school chemistry. This is because such mismatch has been found by several studies to influence learner's ability to process information effectively.

Purpose of the Study

The general purpose of this study was to investigate whether the use of right handed learning resources by left-handed high school chemistry students has any significant effect on their completion rate and thereby their overall achievement in timed chemistry tasks.

LITERATURE REVIEW

Compared to the times 20-30 years ago, the number of left-handed persons has increased. This does not represent a growing trend, it rather reflects a greater individual freedom that permits people to act in accordance to their preferences, individuality and inborn peculiarities (Kula, 2008). However, while left handedness is commonly associated with challenges, generally, left-handers enjoy some advantages over right-handers. For example, a study by Craig and Richeson (2012) reported that experiments on multi-tasking performance showed that when given two tasks to complete simultaneously, left-handers outperformed right-handers. Nevertheless, when instructed to focus on one task at a time, right-handers comparably completed the tasks faster.

In academics, learning challenges are more pronounced since the act of left- to right-calligraphy becomes a major happenstance for left-handers (Milsom, 1995). This is necessitated by left-handers' inability to see their written work because their hand covers the work, a challenge overcome by hooking the hand, an adaptation that is not only awkward but painful as the arm lacks full range of motion control (Hackney, 1997). Left- to right- writing also makes left-handers move the body away from the midline, which is not only uncomfortable in the hand and body positions, but also makes them slow and fatigued when involved in prolonged periods of writing (Malusi, 2014; Milsom, 1995).

Left-handers constantly need to adapt to situations by using their non-preferred hand, which explains the less between-hand differences (Coren, 1989). They therefore get more practice with their right hand and hence find themselves using their non-preferred hand more frequently (Stone et al., 2013) and with more proficiency (Steenhuis & Bryden, 1989). However, left-handers are less consistent in their manual preference compared to right-handers (Crovits & Zener, 1962).

Handedness and Use of Learning Resources

Hand preference is believed to affect human overall cognitive skills (McManus, 2002). During hands-on tasks, learners have an opportunity to familiarize themselves with apparatus, practical techniques and data analysis strategies. Left-handers are likely to experience difficulties using products that require left- right- turning and flexing the muscles. This is because such equipment is solely designed for right-handed use. Since left-handers turn things anti clockwise against the thread, for example fixing a screw, or winding up apparatus by unwinding them, this undertaking is not only strenuous but is sometimes beyond their control (Hughes, Reißig & Seegelke, 2011).

Research has established that the relationship between hand preference and performance is dependent on the degree and direction of manual preference (Flowers, 1975), the movement type and its complexity (Peters, 1981), practice (Chisnall, 2012), number and nature of questions asked and the study participants (Steenhuis, 1999). A study by Annett (1970) found that the speed of placing pegs into close-filling holes was hinged on handedness irrespective of whether one was right- or left-handed, corroborating Flowers (1975) that hand skill depends on the degree of manual preference.

Left-handers show a greater readiness to use the non-preferred hand compared to right-handers when performing an unskilled motor task (Calvert, 1998). Consequently, they may also find themselves performing laboratory tasks whose knowledge and skill has not been effectively proceduralized through automation. Failure to automate knowledge of such skills leads to ineffective information storage, interpretation and retrieval (Eraut, 1994) which may subsequently result in work incompletion leading to lowered performance, especially bimanual tasks which generally involve either using the two hands to hold a single object, using two different objects in combination or an object and a tool to perform tasks (Rigal, 1992). These activities require the co-ordination between both hands which has a direct bearing on hand preference and task performance (Peters, 1981).

Task complexity influences the relationship between preference and performance (Peters, 1981; Steenhuis, 1999), that is, certain tasks whether unimanual or bimanual provoke a stronger hand preference and are faster and more accurately performed using the preferred hand. This is not the case for left-handers because they not only have to work against the norm but also use ungraspable tools. For example, in order to establish how left-handers fair when carrying out fine motor tasks, Darvik (2015) examined right-and left-handers' unimanual and bimanual hand preferences as well as exploring between-hand performance differences. He established that both right-and left-handers performed better with their preferred hand and that right-handers had larger between-hand differences compared to left-handers on all tasks except for intrinsically right-handed tasks (Healey et al., 1986). To further establish this, Rosenbaum and Jorgensen (1992) demonstrated that people grasp objects in an awkward fashion to ensure the "end-state comfort effect" after the movement. This implies that the motor system anticipates future body states and plans final grasp postures prior to movement execution (Hughes, et al, 2011). That is, when a left-hander has to grasp an instructional tool, they have to do it in such a way as to be comfortable at the end of the task.

Timed Laboratory Tasks

During practical examination situations, students particularly may have to deal with more information than they can processes in the stipulated time; i.e., simultaneously recalling relevant theories and techniques, recognizing instructional resources and following task instructions (Johnstone, 1997). Consequently, this may overload their working memory leading to inefficiency in responding to the task demands effectively (Johnstone & Al-Shuali, 2001). Additionally, since learning is influenced by learners' prior knowledge, which may or may not be well-constructed in their long term memory (LTM), this combination often hinders students' attempts to engage effectively between laboratory tasks and related theory (Limniou & Whitehead, 2010). The state can further be compounded if the learner is facing additional challenges of having to deal with ill-fitting learning resources as well as transiting within tasks.

Despite necessary adjustments during instruction, left-handers need to appropriately fit with the available learning resources (Dhara et al, 2008), as well as effectively handle the total cognitive load (Hasler, Kersten & Sweller, 2007). This challenge is more demanding during timed tasks, for example, where left-handers have to manipulate entirely right hand biased learning resources, the requirements on mental effort, mental load and the pressure to meet expectation puts extra demands on them. Jumbling these compounding factors may negatively affect academic performance. This is because the probability of not finishing tasks increases. Notably, failure to finish timed tasks does not always imply a deficiency in content knowledge.

Martella et al., (2003) agrees that transitioning from one activity to another, although essential and inevitable undesirably impacts learner's academic engagements, that is, when between-task transitions (tasks that include shifting from one subject to another) and within-tasks transitions (the discrete activities that happen within given tasks) are done without a glitch, they can have a positive effect on engaged learning. This is because they possibly increase allocated time and decrease chance for disruptive behavior (Lee, 2006). Therefore, it is important to maintain levelness in decreasing the time spent between tasks (Slavin, 2003), a feat that instructors can succeed in if they keep students on-task during within-task transitions by avoiding interruptions or "slowdowns" once an activity has started.

Left-Handers Performance in Chemistry

Typically, left-handers are thought to be more powerful in perception compared to right-handers (Rice, 1998), as well as possessing an enhanced mathematical ability, which involves a high level of visuo-spatial ability (Hermelin & O'Connor, 1986). In the scientific and popular literature, there are consistent reports that left-handers are over-represented among populations of creative artists (Preti & Vellante, 2007) and architects (Peterson & Lansky, 1977), a finding contested by Wood and Aggleton (1991). Although left-handedness is a common trait among learners with specific learning requirements, as a result of their preference for the right-brain thinking (Emore et al, 2006), Paul (2002) agrees that left-handedness is not an obstacle in mental development and not all left-handers experience learning difficulties. For that reason, failure to complete tasks and probably low academic outcomes as a result

should not be taken to mean an inability to effectively retrieve information from the memory stores.

A study by Casasanto and Chrysikou (2011) showed that people link motor fluency with graspable objects when the handles of the objects are oriented to make them easy to grasp. Faced with this reality and the bulk of everyday use tools including laboratory learning resources oriented for right-handed users, left-handers have to adapt to use these apparatuses. This adaptation is costly as it not only takes time and effort but may be seen to affect task completion leading to a decrease in academic achievements.

METHODOLOGY

Data for this mixed methods study was collected from 17-20-year-old chemistry students in a co-educational school in Kenya. For the purpose of comparability, the participants were comparable across their cognitive ability, age, experiences and prior knowledge and therefore the single most attribute that was likely to cause the difference in the results, that is performance in chemistry was handedness. The target population was stratified according to male/female, left-/right-handers. The number of left-handers, male and female participants sampled determined the number of the right-handers.

The sampling procedure was multi-staged. All left-handers were purposefully selected in order to establish their population. A Torque test for handedness was done to establish hand and brain dominance (**Appendix A**). Right-handers were stratified into gender then matched random sampling to ensure that the numbers were comparable across handedness and gender was done. There were 11 left-handers (9 males, 2 females) and 11 right-handers (9 males, 2 females).

Instrumentation and Data collection

A laboratory based task (**Appendix B**) required participants to interact with apparatus in order to determine how the rate of reaction between sodium thiosulphate and hydrochloric acid varies with temperature. Participants were also required to determine the concentration of hydrochloric acid. This requirement necessitated evaluation of the learners' performance during and after the task.

A behavior observation protocol (**Appendix C**) was used to monitor participants' time-on-task using the momentary interval time sampling strategy. The observational period was divided into equal time intervals. The protocol had a list of 13 on- and off-task activities. Engaged time behavior was coded as either on-task (a) or actively off-task (b). A sample of 12 participants was randomly selected from the 22 participants (3 left-and 3 right-handed males, 3 left- and 3 right-handed females) for the group discussion (**Appendix C**).

STUDY FINDINGS

The influence of right handed learning resources use and completion rate of tasks in chemistry

During the task taking, on-task and off-task activities were recorded in the observation protocol and the recordings summarized as shown in Fig. 1.
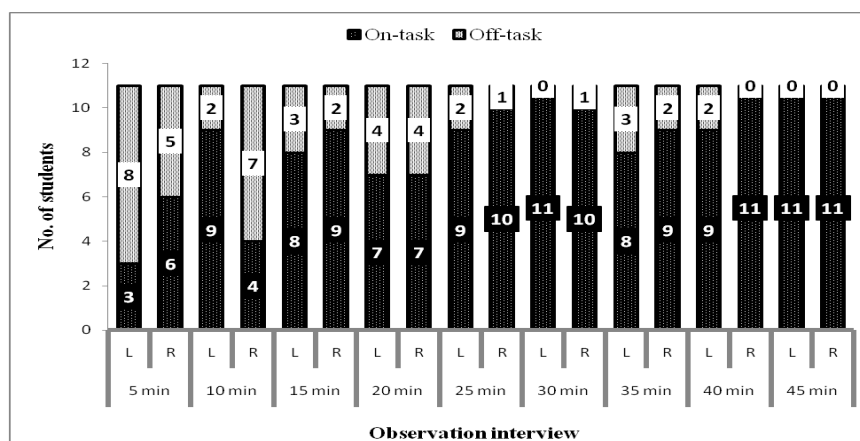

Figure 1: Participants' engagement with the task

During the 1st interval, all participants read instructions. Majority of the right-handers (82%) started fixing and manipulating the apparatus while the bulk of left-handers (73%) started by rearranging the apparatus (what was on the right hand side was moved to the left-hand side of the work station). The rest of the left-handers moved to work from the opposite side of the work station. During the 2nd interval, more right-handers than left-handers were off task. Majority of the left-handers had already started manipulating the apparatus after fixing them.

During the 3rd and 4th intervals, nearly all participants were on-task. One right-hander was idly sitting, looking around and/or fumbling with the apparatus. Few left-handers (4) were still shifting the apparatus from one point to another. During the 5th interval, all participants were on-task except 2 left- and one right-hander who were off-task. Half-way through the task, all participants were on-task. One right-hander appeared to be rubbing all his work and starting the task all over again.

During the 6th interval, all participants except one right-hander were on-task while during the 7th interval, three left-handers and two right-handers were engaged in off-task activities. This trend changed during the next two intervals where all but one participant was seen engaging in off-task activities during the 8th interval. At the end of the task all participants were on-task.

Table 1: Linear Frequencies of Test Scores				
	Participants' handedness	Participants' score	Number on-task	Number off-task
N Valid	22	22	22	22
Mean		9.591	8.27	2.32
Std. Error of Mean		.4234	.457	.467
Median		9.250	8.50	2.00
Mode		8.0[a]	9	2
Std. Deviation		1.9859	2.142	2.191
Variance		3.944	4.589	4.799
Range		7.5	8	8
Minimum		5.5	3	0
Maximum		13.0	11	8
a. Multiple modes exist. The smallest value is shown				

In order to calculate the average participants' engagement time, the formula below was used;

$$\overline{X} = \frac{\Sigma f \times ti}{N ti \times}$$

Where;
ΣfX = sum of the participants on task over an interval
ti = observation interval for participants on task
N = total number of participants observed
X = number of observation intervals

In the overall, left-handers spent 76% (34 minutes) of task time on-task while right-handers spend 78% (35 minutes) of task time doing task related activities.
On average, roughly 8 left-handers were on-task at any given time while findings showed that on average, nearly 9 right-handers were engaged in on-task activities.

Table 2: Participants task engagement

Participants task engagement	Handedness task engagement	N	Mean	Std. Dev	Std. Error Mean
Number of participants on-task	Right-handed on-task	11	8.56	2.404	.801
	Left-handed on-task	11	8.44	2.398	.799
Number of participants off-task	Right-handed off-task	11	2.44	2.404	.801
	Left-handed off-task	11	2.56	2.404	.801

An independent t-test showed no significant difference between on-task engagement of left- and right-handers; -{t(16)=0.196, NS, two-tailed}, meaning that although the average number of right-handers on task (m=9) was slightly higher than that of the left-handers (m=8), this was not statistically significant. In addition, a similar t-test showed no significant difference between off-task engagement of left- and right-handers; -{t(16)=-0.098, NS, two-tailed}, further implying that although the average number of left-handers off-task (m=3) was slightly higher than that of the right-handers (m=2) there was no significant differences between them.

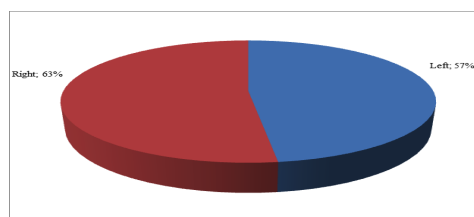After scoring the task, right-handers had an average score of 63% compared to left-handers' 57% task score.

Figure 2: Participants' performance in the laboratory task

An independent t-test showed no significant differences between left- and right-handers' task scores; {t(20)=-0.965, NS, two-tailed}. Despite the right-handers' mean score of (m=10.000; sd=1.342) being slightly higher than that of the left-handers (m=9.182; sd=2.182), this difference was insignificant. This performance index was despite the fact that the participants were matched according to their performance in chemistry based on past tests. Hence, the findings imply that there were intervening variables that curtailed left-handers' performance.

Table 3: Participants Average Task Score

	Participants Handedness	N	Mean	Std. Dev.	Std. Error Mean
Participant scores	Left-handers	11	9.182	2.4726	.7455
	Right-handers	11	10.000	1.3416	.4045

Task completion rate is affected by the interruptions at the work station which in this case came in terms of the positioning of the learning resources, the provision of the ungraspable apparatus some of which required left-to right- turning and therefore, left-handers were forced to turn their bodies in awkward positions. These interruptions also affect the speed at which information is retrieved from the LTM because the learner has to attend to instructions, task requirement and manipulate learning resources simultaneously.

Relationship between use of right handed learning resources and performance in chemistry

Compared to the other science subjects, i.e., Physics and Biology, chemistry was also seen to be *"easier"*, partly because some apparatus as used in Physics *"do not move"* while in Biology *"the theory does not match the practical part"* (L2).
L3 (female) suggested:

> *"I have always felt that I have to put in more effort and time in most of the tasks that I have to do not just in chemistry but in other sciences and especially in Physics. ... I feel things do not flow easily for me. I find the right-handed being favored more by the apparatus and settings used in the laboratory"* L3

L3 felt that more effort and time was required in order to achieve learning goals. This was because she faced challenges manipulating the apparatus, which

corroborates a study by Malusi (2014), that is, left-handers experience difficulties coordinating the movement of both hands simultaneously, especially when clockwise turning by both hands is required. This is because the learning resources used were those that required clockwise turning by both hands.

Teaching and Learning in the School Chemistry Laboratory

The participants preferred group work to individual work, a preference that changed to the preference for individual work over group work as they moved up the academic ladder. Due to being clumsy (Coren, 1992), left-handers prefer having right-handed colleagues in their groups (in the lower forms) so as to get help in handling the more challenging learning resources. As they moved up the forms coupled with practice, and after gaining confidence in the use of the apparatus, the preference changed. For this, L2 said;

> "I like group work because I get assistance from other people (right-handers). However, the right-handed colleagues tend to take control of the set up and ignore us (left-handers). During group work it is my responsibility to choose a position that is most comfortable so that I can also contribute in the task" L2.

Participants also opined that if they had a permanent sitting position during test taking, then it would be easier for teachers to have their stations arranged specifically for the left-hander. This can only happen if teachers are aware of each learner's special needs in the classroom generally and specifically if left-handedness was seen as a special learning need. For example, L4 (male) said;

> "…. lab apparatus should be arranged to suit our individual needs so that we can save on time spend rearranging and getting around the work stations" L4 (male)

At the same time, L3 (female) said that,

> "I find it most comfortable to work while standing on the left hand side of the room. I also find the use of some apparatus quite challenging and I feel it affects my performance. I think there should be a specific area for the left-handed students. I think we should be given some extra time as well as have our apparatus pre-arranged for our sake before the sessions" L3 (female)

In order to determine participants' self-efficacy and opinions about adaptations during practical situations, L5 (male) said;

> "Apparatus and questions (assessment) sometimes affect the results because of compromised precision and speed" L5 (male)

To add on to that, L6 also said that

> "I would have been more comfortable if I was to use apparatus that I can use without feeling like am forcing things to work. Some apparatus makes me feel inadequate" L6 (male)

But L2 a female had this to say

> "To some extent, the quality of my work is affected by the apparatus we use. Many questions that require a lot of manipulation affect my overall performance because I find it challenging coordinating the hands" L2 (female)

Although there was no significant difference between right- and left-handers' performance, left-handers performed a unit less than right-handers. This could have been due to the use of learning resources meant for comfortable use by right-handers (Parish, 2009).

Taking Timed Tasks

The FGD revealed that participants carefully considered each available option before making a decision. These adaptations were costly in terms of time and self-esteem as left-handers feared being accused of cheating in the examinations. For example, as far as adaptations were concerned, L6 opined that;

> "... unless I position myself conveniently I will be uncomfortable. ... I must rearrange apparatus ... to work well in the task. When it is not possible to shift, the fear of being ridiculed by others makes me suffer in silence.... Again ... the burette taps are usually on the right hand side and sometimes we use our right hand. Using two apparatus at the same time is a nightmare, e.g., swirling conical flask and a stop watch. ...can't do both ... my fingers slip when stopping the watch. ...can't stop it on time. The changes ... waste practical time and sometimes make me not finish the exam. When circumstances force me to use the right hand, there is a lot of tension making me feel disadvantaged ... so I end up fidgeting" L6 (male).

Sitting positions and the manipulation of instructional resources was also a challenge that affected the students overall grade. L3 suggested that;

> "Sitting positions are a challenge ...at times we do not get what we prefer. In the lab, it is easy to get confused and panicky when changing positions and rearranging the apparatus. The burette tap is also a challenge to me and more so during multitasking. The changes I do make me not get a good mark in practicals and also my overall grade...." L3 (female).

During practical work, shared work stations are common occurrences. Consequently, left-handers find themselves sharing these work stations with right-handers. When were asked about their views on group work, L1 agreed that;

> "Shared work stations are a problem and I have to rearrange apparatus to suit my needs. The burette and the conical flask is a problem to handle and I must use both hands. ... I feel it affects my performance because I am not comfortable holding the apparatus and the chemicals can also corrode my skin. It would help if we are given time to rearrange the apparatus before the beginning of a task" L1 (female).

Although R4 a male right handed student had no problem sharing a work station with left-handers, he was of the opinion that they tend to mess with reagents. He emphasized that;

> "Work stations are not a problem ... sharing apparatus is ... sometimes I ...move the apparatus to the disadvantage of the lefties. ...when you are working with them (lefties) they ... mess the reagents. It is annoying... they always do something funny with what we are given to work with..." R4 (male)

Further probing on how shared work stations contributed to the inability to finish timed tasks, L5 opined that extra time would help them complete their work.

Evidently, some learning resources hinder the performance and perfection of students' work in chemistry. The arrangements of work stations prior to a major examination have the potential to influence learner' performance. Right-handers claimed that left-handers disorganize the provided task requirements thereby compromising task results during group work. The facet of safety in the laboratory was also mentioned as a constraint for left-handers. These constraints and mismatches have the potential to increase cognitive load which in the long run hinders effective information processing. In the case of left-handers, automation

(which lowers cognitive load) is negatively affected because of using 'ungraspable' learning resources which divert their conscious attention towards incoming information.

DISCUSSION OF STUDY FINDINGS

Left-handers spend more time handling, fixing and manipulating learning resources compared to right-handers. Therefore, left-handers have to deal with more extrinsic load (Johnstone, 1997) which consequently overloads their working memory, in turn hindering effective response to task demands (Johnstone & Al-Shuali, 2001; Hasler, et al. 2007). The ensuing struggle costs time. Further, left-handers still have difficulties coordinating the movement of the right and left hands simultaneously, especially when clockwise turning by both hands is necessary (Ruecker & Brinkman, 2001).

Taking and finishing timed tasks

During end of course examinations, work stations are prepared for right-handers. Left-handers are left to choose the adjustments to make in order to cope. Left-handers also find themselves sharing work stations with right-handers who view them as being a bother (Coren, 1992). It would therefore seem plausible if left-handedness was viewed as a special learning need.

Participants experience with selected laboratory tools

Learning resources that require flexing the muscles of both hands, those that require eye-hand coordination, reading from left to right (meter rules, measuring cylinders), as well as multitasking manipulations cause left-handers discomfort during use as it interferes with both precision and speed (Rueckert & Brinkman, 2001).

Adaptations and adjustments left-handers make so as to work comfortably and remain on-task during laboratory tasks make left-handers preferring individual work to group work as they move up the academic ladder. Individual work would help them build self confidence in the performance of tasks, automate procedural knowledge and skills (Mousavi, et al., 1995) as well as familiarize themselves with learning resources. Such familiarity frees most of working memory hence reducing extraneous load (Sweller, 1998).

CONCLUSION

On average, findings indicated that more left-handers spend extra time off-task compared to right-handers. Their performance was also a point less compared to right-handers. Therefore, left-handers have to not only work faster, they also have to put in more effort and time in order to complete timed tasks and post favorable performance.

RECOMMENDATIONS FOR FUTURE RESEARCH

This study demonstrates that the use of right-handed learning resources may have a negative effect on left-handers' performance in timed chemistry tasks. The study is limited by the small number of participants studied. To increase construct and concurrent validity, time-on-task samples from different grades and more students should be obtained. Further, correlating time-on-task data to classroom achievement, gender and grades would be helpful as well. Replications of this study are needed that compare time-on-task differences using shorter time intervals. These additional investigations should provide intuition into the use of right handed learning resources and its effect on the overall achievement of left-handers in practical chemistry.

REFERENCES

Annett, M. (1970). A classification of hand preference by association analysis. *British Journal of Psychology*, 61(*3*), 303-321.

Annett, M. (2002). Handedness and brain asymmetry: *The right shift theory*. East Sussex: Psychology Press.

Annett, M. & Manning, M. (1989). The disadvantage of dextrality for intelligence. *British Journal of Psychology*, *80*, 213-226.

Bishop, D. (1990). *Handedness and Developmental Disorder*. Lawrence Erlbaum Associate Publishers: Hove, UK.

Björklund, T. A. (2013). Initial mental representations of design problems: *Differences between experts and novices. Design Studies*. 34(*2*), 135-160. DOI: 10.1016/j.destud.2012.08.005. Accessed Nov, 2017

Bryden, M. & Steenhuis, R. (1997). The Assessment of Handedness in Children. In J. E. Obrzut & G. W. Hynd (Eds.), *Neuropsychological Foundations of Learning Disabilities. A Handbook of Issues, Methods and Practice.* (S. 411-436). San Diego: Academic Press.

Calvert, G. (1998). Quantifying hand preference using a behavioral continuum. Laterality: Asymmetries of Body, Brain and Cognition, 3(*3*), 255-268.

Casasanto, D. & Chrysikou, E. (2011). When Left Is "Right": Motor Fluency Shapes Abstract Concepts. *Psychological Science,* 22(*4*), 419–422. Accessed from pss.sagepub.com in April 2011.

Chisnall, R. (2012). A Brief History of Handedness Research. In J. D. Dunham, Todd (Ed.), Handedness; Theories, Genetics and Psychology (pp. 45-68): Nova Science Publishers.

Coren, S. (1989). Left-handedness: Behavioral implications and anomalies (Advances in Psychology, No. 67). Amsterdam: North-Holland

Craig, M. & Richeson, J. (2012). Coalition or derogation? How perceived discrimination influences intraminority intergroup relations. *Journal of Personality and Social Psychology,* 102(*4*), 759-777. doi: 10.1037/a0026481

Crovitz, H. & Zener, K. (1962). A group-test for assessing hand-and eye-dominance. *The American journal of psychology*, 271-276.

Darvik, M. (2015). The Degree of Hand Preference and Hand Performance on Bimanual Tasks in Right- and Left-Handers. Retrieved Oct 2015

Dhara, P., Khaspuri, G. & Sau, S. (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.

Emore, E., Ebeye, O., Odion-Obomhense, H. & Igbigbi, P. (2008). A Look at the Effect of Hand Dominance on Learning. *Journal of Applied Sciences, 8,* 173-176. Accessed from http://scialert.net/abstract/? Aug 2013.

Eraut, M. (1994). Developing professional knowledge and competence. London: The Falmer Press.

Flowers, K. (1975). Handedness and controlled movement. *British Journal of Psychology*, 66(*1*), 39-52.

Greenwood, C., Horton, B. & Utley, C. (2002). Academic engagement: Current perspectives on research and practice. *School Psychology Review, 31*, 328–349.

Hackney, C. (1997). Left handed in a right handed world. Report No. CS 215824). Washington CD.: Office of Educational Research and Improvement. (ERIC Document Reproductive Service No.ED. 406692).

Hasler, B., Kersten, B. & Sweller, J. (2007). Learner Control, Cognitive Load and Instructional Animation. *Appl. Cognit. Psychol., 21,* 713–729. Accessed August, 2013 from (www.interscience.wiley.com).

Healey, J., Liederman, J. & Geschwind, N. (1986). Handedness is not a unidimensional trait. Cortex, 22(*1*), 33-53.

Hermelin, B. & O'Connor, N. (1986). Spatial Representations in Mathematically and in Artistically Gifted Children. *British Journal of Educational Psychology, 56,* 150–157.

Hibbard, M. Van Wagenen, L., Lewbel, S., Waterbury-Wyatt, S., Shaw, S., Pelletier, K., Larkins, B., Dooling, J., Elia, E., Palma, S., Maier, J., Johnson, D., Honan, M., Nelson, D. & Wislocki, J. (2015). Teacher's Guide to Performance-Based Learning and Assessment. Accessed in August 2015

Hughes, C., Reißig, P. & Seegelke, C. (2011). Motor planning and execution in left- and right-handed individuals during a bimanual grasping and placing task. *Acta Psychologica.* Retrieved in October 2015 from doi:10.1016/j.actpsy

Johnston, D., Nicholls, M., Shah, M. & Shields, M. (2009). Nature's experiment? Handedness and early childhood development. *Demography, 46*, 281-302.

Johnston, D., Shah, M. & Shields, M. (2007). Handedness, Time Use and Early Childhood Development. Retrieved August 2013.

Johnstone, A. (1997). Chemistry Teaching—Science or Alchemy? *Journal of Chemical Education, 74*(3), 263-268.
Johnstone, A. & Al-Shuaili, A. (2001). Learning in the laboratory: Some thoughts from the literature. *University Chemistry Education*, 5(*2*), 42-51. Retrieved April 2012 from http://www.rsc.org/images/.

Kula, P. (2008). Teaching left-handed primary school pupils in Estonia. *Journal of Teacher Education for Sustainability, 9*, 58–67. Retrieved July 2011.

Lance, W. (2005). *Left-handed children in a right-handed world*. Retrieved May 2012 from http://www.iched.org/cms/scripts/page.php?site_id

Lee, D. (2006). Facilitating transitions between and within academic tasks: An application of behavioral momentum. *Remedial and Special Education, 27*, 312–317.

Limniou, M. & Whitehead, C. (2010). Online general pre-laboratory training course for facilitating first year chemical laboratory use. Cypriot Journal of Educational Sciences, 5, 39-55. Retrieved June 2013 from www.worldeducation-center.org/index.php/cjes

Mahajan, D. & Singh, G. (2005). University Students Performance in Organic Chemistry at Undergraduate Level: Perception of Instructors from Universities in the SADC Region. A paper Presented at the SAARMSTE Conference in January 2004 at Cape Town, South Africa.

Malusi, B. (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).

Martella, R., Nelson, J. & Marchand-Martella, N. (2003). *Managing disruptive behaviors in the schools*. Boston: Pearson Education.

Martinez, E. & Brock, S. (2009). Time-on task. The Gale Group, Inc. Retrieved Sept 2014.

McManus, I. (1997). The inheritance of left-handedness. CBA Found Symp 1991:162:251-67 discussion 67-81.

Milsom, L. (1995). Left-handed children are they losing out? *Educational media international, 32*, 107-108.

Mousavi, S., Low, R. & Sweller, J. (1995). Reducing Cognitive Load by Mixing Auditory and Visual Presentation Modes. *Journal of Educational Psychology,* 87*(2)*, 319-334. Retrieved April 2011.

Muya, W. (2000). Great expectations as new system seems likely. Daily Nation on web. URL:http://www.nationaudio.com/News/DailyNation/2202000/News59.html

Orji, N. (2014). Relationship between Science Teachers Classroom Management Effectiveness and Students Outcomes in Chemistry. *International Journal of Modern Education Research,* 1(*1*), 11-14

Otieno, O. (2013). Determinants of students' poor performance in chemistry in public secondary schools of Kwale County, Kenya. Retrieved from http://ir-library.ku.ac.ke May 2014

Parish, A. (2011). Effect of handedness on gross motor skill acquisition among college undergraduates. Retrieved July 2013.

Paul, D. (2002). *The Lefthander`s Handbook*. England: The Robinswood Press. Peters, M. (1981). Handedness: effect of prolonged practice on between hand performance differences. *Neuropsychologia*, 19(*4*), 587-590.

Peterson, J. & Lansky, L. (1977). Left-Handedness among Architects: Partial Replication and Some New Data. *Perceptual and Motor Skills*, *45,* 1216–1218.

Preti, A. & Vellante, M. (2007). Creativity and Psychopathology: Higher Rates of Psychosis Proneness and Nonright-Handedness Among Creative Artists Compared to Same Age and Gender Peers. *Journal of Nervous and Mental Disease*, *195*, 837–845.

Rice, P. (1998*). Human development* (3[rd]ed.). New Jersey: Prentice Hall.

Rigal R A. (1992). Which Handedness: Preference or Performance? *Perceptual and motor skills.* Accessed from http://journals.sagepub.com/home/pmsin May 2014

Rosenbaum, D.A., & Jorgensen, M.J. (1992). Planning Macroscopic Aspects of Manual Control. Human Movement Science, 11(1-2), 61–69.

Rouet, J. (2009). Managing cognitive load during document-based learning. *Learning and Instruction.* Retrieved May 2014.

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.

Silverman, S. (2009). Stance for Left-handed Golfers. Retrieved in June 2013 from: www.*golflink.com./how_317_stance-lefthanded-golfres.html.*

Slavin, R. (2003). *Educational psychology*: Theory and practice. Boston: Pearson Education.

Steenhuis, R. (1999). The relation between hand preference and hand performance: What you get depends on what you measure: *Asymmetries of Body, Brain and Cognition*, 4(*1*), 3-26.

Steenhuis, R. & Bryden, M. (1989). Different dimensions of hand preference that relate to skilled and unskilled activities. *Cortex*, 25(*2*), 289-304.

Stone, K., Bryant, D. & Gonzalez, C. (2013). Hand use for grasping in a bimanual task: evidence for different roles? *Experimental brain research*, 224(*3*), 455-467. [02.2013]
Sweller, J. (1998). Cognitive load during problem solving: *Effects on learning. Cog Sci*, *12*, 257–285.

Tunde, O. (2014). Analysis of Students' Achievement in Analytical Chemistry among the University Students in Nigeria, *International Journal of Education and Research, 2(2),* 1-6

Van De Weghe, R. (2006). *Research matters: What is engaged learning? English Journal, 95(3)*, 88–91.

Williams, S. (1987). Differences in academic performance at school depending on handedness: Matter for neuropathology? *Journal of Genetic Psychology*, *148*, 469-478.

Wood, C. & Aggleton, J (1991*). Handedness in 'fast ball' sports: do left-handers have an innate advantage? British Journal of Psychology, 80,* 227–240.

Contact email: bentamwikali70@gmail.com

Appendix A: Torque test for Handedness

To be used by the researcher to determine participants' handedness
Name of participant---
Age of participant---
Sex ------M----------------------F----------------------------
Date ---

Procedure
The teacher will ask each of the left-handed participants to come with a piece of paper and a pencil. He/she will then ask them in turns to write his/her name with one hand the circle it.

The teacher then asks the student to draw using the other hand and draw a circle round the name. He/she then notes and records the direction of the circle.

1. Which hand produces the best handwriting?   L……… R……..
2. Were both circles drawn clockwise?   Yes……. No ……
3. Were both circles drawn clockwise?   Yes……. No ……
4. Was one circle drawn clockwise and the other counter-clockwise? Yes ...No……

NB: This is to help the researcher determine the left-handers and the ambidextrous

•   The hand that produces the best handwriting is the dominant hand
•   If the circles were drawn clockwise, the right-brain is dominant,
•   If the circles were drawn counter-clockwise, this indicates left-brain dominance.
•   One circle clockwise and the other counter-clockwise shows mixed dominance.

(Adopted from Kalafut, 2008)

Appendix B: Students' Classroom Observation Schedule

(Adapted from http://lefthandedchildren.org copyright @ 2006 and modified)
This checklist is to be filled by the researcher as evidence of participant observation in the laboratory during the practical session. It is to be completed for every individual participant.

Observation Checklist

Is there evidence that participant is changing position during the interaction with the apparatus? ....
Are they facing the front of the classroom? Observed ………. Not Observed………...
Does it inconvenience others working next to them? Observed…… Not Observed.....

Classroom Observation Sheet

For each of the participants the observer will check and record in the observation sheet the main activity the participant is involved in. A participant can have multiple entries

Activity	5	10	15	20	25	30	35	40	45
(a) On Task									
(b) Off Task									
1. Rearranging apparatus (b)									
2. Looking around (b)									
3. Fixing the apparatus (a)									
4. Manipulating the apparatus(a)									
5. Fidgeting with hands (b)									
6. Sitting idle (a, b)									
7. Reading instructions (a)									
8. Consulting with teacher (a)									
9. Moving about without doing task related activities (b)									
10. Changing positions (b)									
11. Consulting with colleagues (a)									
12. Doing calculations (a)									
13. Too much rubbing (b)									
Any other activity student is doing									
Total number of times ON task									
Total number of times OFF task									

On-task all activities student does either listening to/reading instructions, manipulating apparatus and/or working on the calculations that are aimed at promoting learning of the content/achieving the learning goal (procedural and content issues)

Off-task: any other activity student does other than the actual task that can interfere with the achievement of the learning goal (non-academic issues)

Appendix C: Task worksheet

This practical task consists two parts. In part 1 (a), you are required to determine how the rate of reaction between sodium thiosulphate and hydrochloric acid varies with temperature. You are also required to determine the concentration of hydrochloric acid. In part 1 (b), you are required to standardize the hydrochloric acid provided. Follow the instructions correctly and write your answers in the spaces provided below each question.

Name--
Sex----------- (M) ---------------------------- (F) --------------------
Date---

1a). **You are provided with:**
- Sodium thiosulphate containing 7.9g of the solute in 100cm^3 of solution.
- Hydrochloric acid.

You are required to:
- Determine how rate of reaction between sodium thiosulphate and hydrochloric
- acid varies with temperature.
- Determine the concentration of hydrochloric acid

Instructions to participants

Procedure 1:
Measure 10cm^3 of sodium thiosulphate using a measuring cylinder and transfer it into a clean conical flask. Make a cross(x) on a white piece of paper and place the flask on the cross(x) on the paper. Using another clean measuring cylinder, measure 10cm^3 of hydrochloric acid and note its temperature; transfer the hydrochloric acid into the conical flask containing sodium thiosulphate and immediately start the stop watch. Swirl the mixture and record the time taken for the cross(x) to be blocked. Repeat the procedure at varying temperatures and fill the table below.

Table

Volume of sodium thiosulphate (cm^3)	10	10	10	10	10	10
Volume of hydrochloric acid (cm^3)	10	10	10	10	10	10
Temperature of hydrochloric acid (^{o}C)	25	30	40	50	60	70
Time taken for cross to be blocked (sec)						
Reciprocal of time __I__ or.. I Time t						

a) Using the table above plot a graph of reciprocal of time (y-axis) against temperature. (3mks)
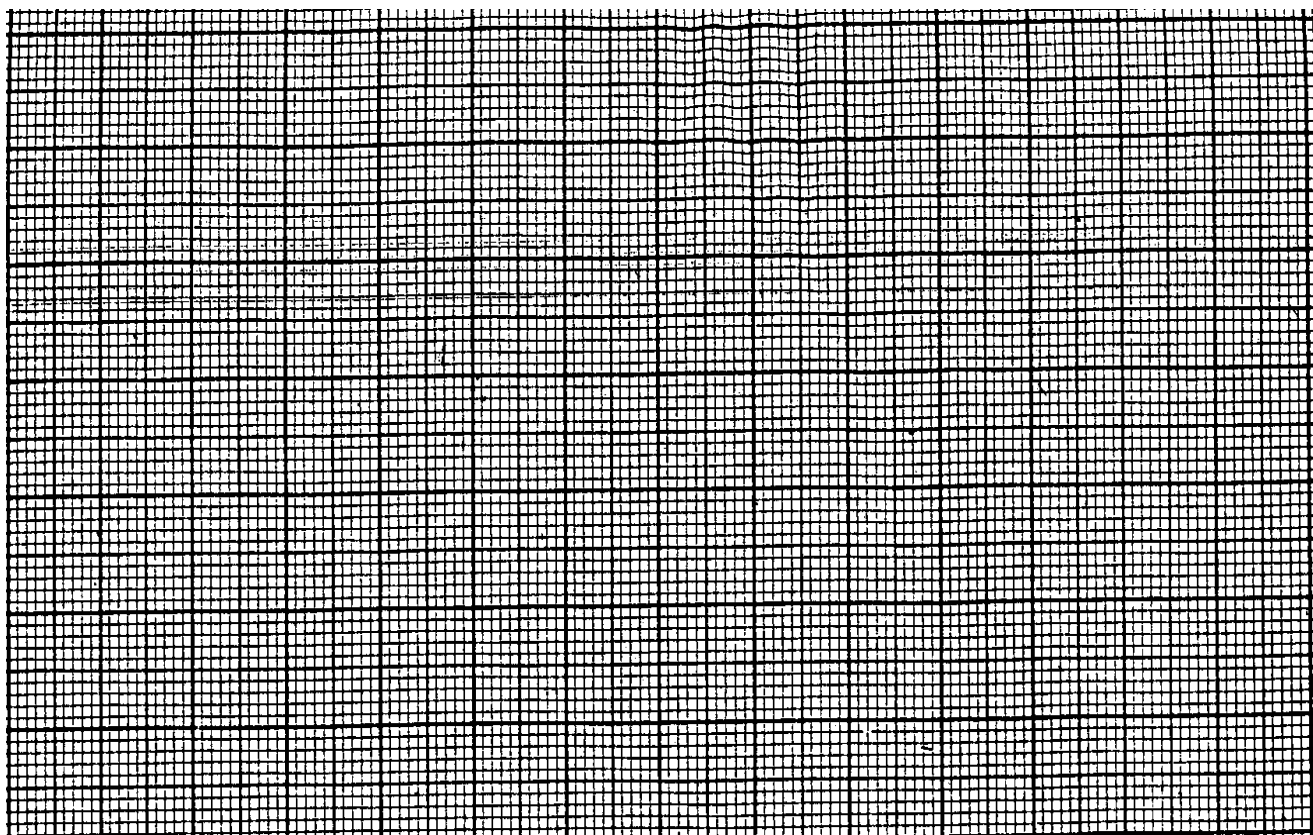
b) From the graph determine the time required for the reaction to be complete at 55°C. (1mk)

……………………………………………………………………………………………………

……

c) What will be the temperature for the reactions if time taken for complete reaction in 15 secs. (1mk)

……………………………………………………………………………………………………

……

d) How does the rate of reaction vary with varying temperature? Explain
        (2mk)

……………………………………………………………………………………………………

……

e) Given the equation for the reaction in the flask to be

$Na_2S_2O_3 + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O + S_{(s)} + SO_{2(g)}$

(i) Calculate the moles of sodium thiosulphate that are in $10cm^3$ of sodium thiosulphate (1mk)

……………………………………………………………………………………………………

……

(ii) Workout the moles of hydrochloric that reacted with $10cm^3$ of sodium thiosulphate (1mk)

………
………
(iii) What is the concentration of the hydrochloric acid?
        (1mk)
………
……

OBSERVATION CODES

On-task is when student is actively attending to the assigned work (writing, reading aloud, raising a hand to answer a question, talking to the teacher/peer about the assignment, looking up a word in the dictionary, typing an essay in the computer)
Off-task is those times when a student is passively attending to the assigned work (listening to a lecture, looking at an academic worksheet, reading the assignment silently, looking at the blackboard during teacher instruction, listening to a peer respond to a question)

Off-task motor defined as any instance of motor activity that is not directly associated with an assigned academic task
- ✓ Engaging in any out of seat behavior (buttocks not in contact with seat)
- ✓ Aimlessly flipping the pages of a book
- ✓ Manipulating objects not related to the work (playing with paper clip, twirling a pencil, throwing paper, folding paper)
- ✓ Physically touching another student when not related to academic work
- ✓ Turning away from one's seat oriented away from the classroom activity
- ✓ Bending or reaching for something on the floor
- ✓ Drawing/writing that is not related to the task
- ✓ Fidgeting in one's seat (engaging in repetitive motor movement for at least three consecutive seconds)

Off-task verbal any audible verbalizations that are not permitted and/or are related to the assignment
- ✓ Making any audible sound, e.g., whistling, humming, forced burping etc
- ✓ Talking to other students about issues unrelated to an assigned academic task when such talk is prohibited by the teacher
- ✓ Making unauthorized comments or remarks
- ✓ Calling out answers academic problems when the teacher is not specifically asked for an answer or permitted such behavior

Off-task passive those times when a student is passively not attending to an assigned academic activity for a period of at least three consecutive seconds within an interval
- ✓ Student is quietly waiting after the completion of an assigned task but is not engaged in an activity authorized by the teacher
- ✓ Sitting quietly in an unassigned activity
- ✓ Looking around the room
- ✓ Starring out through the window
- ✓ Passively listening to other students talk about issues unrelated to the assigned academic activity

Appendix D: Focus Group Discussion Guide

This schedule was used as a guide by the researcher to elicit responses from the focus group constituted from the team of students that did the chemistry laboratory task.

➢ Who or what influenced your choice of chemistry as an examinable subject?

➢ How would you rate your Performance in chemistry from form two to the current? *Probe for reasons for this*

➢ What is your opinion about Performance work in chemistry (is it necessary)? *Probe for reasons of responses given*

➢ Sometimes you are required by the task to do more than one activity at a time. Are there challenges that you encounter during such times? *Find out how the participants surmount the said challenges*

➢ In your opinion, do you think you have to put in a little more effort than the right-handed students and especially in practical examinations (tasks)? *Probe for reasons for the responses*

➢ Will you continue doing chemistry related courses? More advanced and complicated resources will be used during the training or in the line of work. What does that make you feel?

➢ Given an opportunity, what would you tell your fellow students, your teachers, your parents and policy makers to do in order to make chemistry learning friendlier to students and especially the left-handed learners? What about examinations?

➢ How does the work load in chemistry compare to that of other science subjects?

➢ Is your overall performance affected by your handedness especially because of practical work?