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Ministry of General Education

Assessment of STEM Education Implementation in STEM Secondary Schools

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Executive Summary

The implementation of STEM Education in Zambia started in the year 2020 with fifteen out of the targeted fifty-two piloting STEM schools. The operationalization of the Transitional STEM Education Curriculum was executed at two secondary school entry grade levels (8 and 10). The Transitional STEM Education Curriculum was characterised by a major shift from the mainstream positivist teaching and learning approaches to constructivism in which learners were to take the central stage. To this effect a survey was conducted to assess the management and implementation of the STEM Education Curriculum in STEM schools. The purpose was to assess the effectiveness of the implementation of the Curriculum and to provide early interventions from emerging issues. The undertaking also paved way to planning for assessment for learning as well as assessment of learning. Specifically, the main objectives for this pursuit were:

a) To determine the existing status of the STEM Schools in terms of general school information
b) To assess teachers understanding of STEM Education Curriculum intentions and implementation
c) To evaluate how the STEM Education Curriculum is being delivered through lessons
d) To establish the attainment of the STEM Education Curriculum by the learners.

This report presents and discusses findings on the management and implementation of STEM Education Curriculum in the fifteen STEM schools in Zambia. The major findings from the monitoring exercise were:

General School Information

All of the STEM schools had qualified Head teachers and Heads of Departments capable of running the STEM institutions, with 47% of Head teachers having a second degree. Furthermore, the majority of Head teachers were trained in subjects other than Science, Technology and Mathematics. The number of teachers in STEM Departments varied from school to school with sufficient average numbers. However, the numbers of teachers for Design and Technology and for Hospitality and Tourism were substantially low considering the fact that these two subjects are separate Departments in the STEM Education dispensation with rising enrolments in the subjects.

All the schools reported that they had sufficient classrooms, most of which were functional. However, some schools did not have some specialized rooms especially Mathematics and Agricultural Science laboratories. Amongst the STEM Education Curriculum pathway choices, Hospitality and Tourism STEM Education Curriculum was least offered in the Provincial STEM Schools. The general perception on STEM Education by the learners was that this type of education very good for their personal development and for the development of the nation. They also appreciated the new teaching approaches that their teachers employed which entailed more of research work. However, there was need to equip the schools with more computers, internet provision and other research facilities.

STEM Education Curriculum Intentions and Implementations

On average teachers understood the STEM Education Curriculum intentions. However, there was inability to excerpt correct aspects of subtopics, outcomes and content knowledge from the Curriculum to use in planning for lessons. This could suggest that there was influence from the 2013 Curriculum and heavy reliance on textbooks which persuaded the choice of these aspects. Further, there was average collaborative lesson planning as teachers engaged in consultative sharing of knowledge on teaching and learning strategies. However, plans on how to handle misconceptions and assess learning were not adequately explored, hence hindering the achievement of learning outcomes. Regardless of the varied lesson plan formats used, it was found in this research that most teachers utilized predetermined lesson plan templates. The implication of this is that there could be limited creativity in terms of incorporating essential elements needed to produce a critical, creative and analytical learner. In the event that predetermined lesson plan templates are used, a soft copy would be better to enable teachers to add as much text and figures as possible to enrich their planning for the lessons.

While most teachers displayed proficiencies on constructing lesson rationales, there was insufficient depth of content information and relevance provided. This could mean that in as much as teachers were able to indicate the rationale aspects, they were not very much grounded in how elaborate the aspects should be. Additionally, it was observed that discussion, which is not a method in principle, was the most prevalent teaching method planned to be used in most of the lessons. The effect of this is that, teaching and learning activities would not be well organized in preference to STEM learning requirements.

As regards to planning for lesson introduction, the research found out that key tasks were not employed in most lesson plans to set the tone and to direct the flow of the lesson. Instead ordinary and quick-answer questions were planned to be used by most teachers as introductory activities. Key tasks are essential in STEM Education as lesson starter activities, either as scenarios, key questions or problem statements, because they tend to bring learners to focus on the task and stimulate their thoughts. This is vital to the learners as such tasks can help them to become critical thinkers, creative and analytical participants in the learning process.

It was established that the flow of lesson development on most lesson plans was positivist in nature where the teacher was earmarked to take centre stage, indicating the up-hill battle that Teacher Education has to conquer as they voyage the STEM Education. However, a few lesson plans indicated constructivist flow of lesson development. This should be appreciated and viewed as a paradigm shift towards constructivism in the way of learning and hence requires consistent support and reinforcement. This approach also entails sustenance amongst educationists at all levels including teacher preparation institutions and other professional development stakeholders.

Regarding lesson conclusion, it was found that generally the aspects planned for concluding lessons, which are the Curriculum, teacher and learner, were not meeting the minimum standards across all the subjects, leading to inadequate attainment of learning outcomes. Therefore, teachers should always consider these aspects as they plan the conclusion of the lesson. Generally, teachers referred to appropriate resource materials during lesson planning. However, e-resources were not part of the resource materials consulted when planning for lessons, implying that teachers planned the lessons hurriedly and forgot to include all the relevant information regarding references. Further, on planning for teaching and learning aids, the findings showed that the lesson plans at both Senior and Junior levels did indicate teaching and learning aids to be used during the lessons. However, it was not clear on who would use the indicated teaching and learning aids as most plans only listed the aids. It is therefore, recommended that teacher SBCPD activities should include ICT literacy skills and how to reference resource materials, among others.

STEM Education Curriculum Delivery

The general observation regarding Curriculum implementation was that most lessons were executed as planned. However, there were some minor deviations in some lessons where the teachers either did not complete the lesson as indicated on the lesson plan or changed the lesson activities as the lessons progressed. The differences exhibited at planning and implementation might be that teachers were inadequately prepared for the lessons or they might have considered planning as a formality to adhere to the standards that one needed to have a lesson plan before teaching. It might also mean that there were unplanned introductory aspects presented in the lessons which might not have the ability to engage the learners and bring out their inquisitiveness as expected. This consequently impeded the acquisition of desired learning outcomes. Further, as indicated under planning for lessons, the use of more ordinary questions was evidence of the substantial positivist influence on the teachers' pedagogical skills and hence the struggles to adapt to constructivist approaches.

It was observed in most lessons that teachers employed cooperative learning, at both Junior and Senior levels, which is an indication that teachers were able to accord learners opportunities to engage, interact, critique and share ideas during teaching and learning. However, in so far as group strategies bring widespread benefits, dynamics of cooperative learning should be well considered in order to ensure that every learner contributes fairly and attains better understanding of concepts. This is so because in most lessons observed, the numbers of learners in groups were too big for the individual participants to effectively contribute. Additionally, the fact that there were attempts of lesson activities flowing in constructivist manner is indication enough that teachers were slowly adapting to this way of teaching and learning. This is important in STEM Education as constructivist approaches help learners to reflect on existing knowledge, construct new knowledge, evaluate the merits and demerits of newly constructed knowledge, and acquire skills and values based on their experiences.

Most of the lessons conducted during this research were not consolidated in a manner in which learners would acquire the main ideas and have uncertainties cleared before the end of the lesson. In STEM Education, effective constructivist strategies should include reinforcement of lesson ideas. Therefore, lesson consolidation is important as it reinforces learning points that learners have to process and make sense of in order for conceptual understanding to take place. This can be done by both the teacher and the learners, with the teacher playing a critical role of creating suitable opportunities for the confirmation of facts. Clarifying concepts and principles during lesson consolidation entails discipline, careful observation and focus on details as the lesson progresses.

From the findings, it was apparent that some teachers did not understand what constitutes lesson summary and evaluation. Most of the summaries were in form of simple question and answer statements such as *"Are there any questions"*. Good lesson conclusions should help organize learnt concepts into meaningful contexts in order to make learners to better understand what they have learnt and provide a way in which to assess the learning. To ensure that lesson conclusion aspects are effectively implemented, teachers' content knowledge and pedagogical skills need to be enhanced. This can be done through strengthened system of subject communities of practice.

At the time the 2019 Transitional STEM Education Curriculum was phasing in for Grades 8 and 10, the 2013 Curriculum was still being offered to Grades 9, 11 and 12 learners, implying a dual implementation of the Curricula in a STEM school. This led to non-adherence to the stipulations outlined in the 2019 Transitional STEM Education Curriculum in as far as School-Based Continuous Assessment (SBCA) and research were concerned. As a result, most of the SBCA conducted for STEM learners was a replica of what was offered to non-STEM Education learners. This was at the insistence by some school administrators that all learners in their schools were supposed to follow the usual assessment criteria, including mid-Term tests, regardless of the differences in 2013 and 2019 Curricula. To this effect, it becomes a source of concern because it might affect the final continuous assessment results due to work backlog. The other reason for non-administration of SBCA and research might be inadequate time between the commencement of STEM Curricula implementation and the monitoring survey exercise. However, in STEM Education continuous assessment could be administered even on the commencement day depending on the activities that learners were engaged in. Further, some school administrators, together with the teachers, might not have read both the assessment criteria and research sections of the Curriculum in order to understand how they were to be conducted resulting in not having learners assessed as guided within the documents sent to the schools. It is, therefore, recommended that STEM school administrators and teachers be guided further in order to strengthen their skills in the management of SBCA and research for effective implementation of the 2019 STEM Education Curriculum without underplaying the 2013 Curriculum. It is further recommended that teachers be capacity-built in research skills and that they should carry out research and publish their works in the Zambia Journal of Teacher Professional Growth (ZJTGP) and Zambia Educational Journal for Science, Technology, Engineering and Mathematics (ZEJSTEM) in order to up skill their capacity in research work. This will enhance sharing of knowledge and best practices.

STEM Education Curriculum Attainment

On Curriculum attainment, the research used Scientific Skills as benchmarks to determine the level of learner progression as the learners developed these skills. The skills were categorized in 5 domains namely; Acquisitive, Organisational, Creative, Manipulative and Communicative. The skills were measured during lesson delivery. The findings from the research revealed that Acquisitive, Organisational and Communicative skills were prominently demonstrated by learners. However, the Creative and Manipulative skills were lowly exhibited in almost all the lessons across the subjects. Further, it is not clear what was being organized and communicated because the Creative and Manipulative Skills, which are the main drivers of STEM Innovation, were not demonstrated as expected in most of the lessons observed in all the STEM subjects. The low exhibition of these important skills is of prime concern as it entails that learners would not be accorded with prospects to make something new or figure out ways of doing things. Learners would also be deprived of the ability to interact with materials and equipment so as to understand underlying principles and further generate novel or unorthodox solutions. This could be due to the fact that teachers had inadequate content knowledge and pedagogical skills and hence were still struggling to plan for activities that could elicit higher order skills such as Creative and Manipulative. It was further revealed that the rating *"Not Applicable"* was quite prominent in all the skills especially in the Creative and Manipulative skills. This is equally a source of concern as it might be a sign that teachers as well as observers had challenges to conceptualise these skills. The implication of this is that interventions may be misdirected as the presented data may not be adequately reliable. It is, therefore, imperative that tailor-made capacity building programmes which include focus on the "Way of Seeing" in the teaching and learning process should be strengthened at all levels of STEM Education delivery.

On one hand, the positive strides in the implementation of STEM Education Curriculum implied that there was guarantee to equip Zambian STEM learners with learning, life, and media literacy skills which are important attributes in contemporary society. On the other hand, the inadequacies suggested impediments in attainment of Curricula intentions. In order to reach desirable levels of STEM Education implementation, it is therefore, recommended that there be targeted interventions such as; sustainable in-service capacity building of school administrators, STEM teachers and trainers in Pedagogical Content Knowledge, STEM Education Curriculum content readjustments and review as well as, to a greater extent, continued support of STEM Education.

1. Introduction

Background

STEM education has progressively become a world-wide norm in the pursuit to attain sustainable development. To this effect most education systems have embarked on learning that will facilitate the development of contemporary learners with corresponding 21st Century skills. Therefore, the Republic of Zambia through the Ministry of Education started the implementation of STEM Curricula. Before the implementation of the STEM Education, there was a survey conducted in December 2018 which revealed that the performance of technical schools was declining necessitating the establishment of STEM Education. In order to balance education provisions and aspirations of the country Cabinet Office approved the establishment of 52 STEM Education schools countrywide in October 2019 in schools countrywide. Taking a phased approach, in January 2020 implementation of STEM Education started in fifteen schools. To this effect, the directorate of National Science Centre (DNSC), which is responsible for STEM Education in the country, undertook training of STEM teachers from the fifteen pilot schools. Thereafter, the actual school implementation of the Transitional STEM Curricula began in February, 2020 which was followed by monitoring to ascertain the effectiveness and management of the teaching and learning processes. The monitoring of STEM implementation exercise was done by five teams from 24th February to 7nd March 2020. All the fifteen schools in the provinces were monitored targeting headteachers, STEM HoDs, teachers and learners. Data was collected from lessons observations, interviews and questionnaires using both quantitative and qualitative approaches. The monitoring exercise was done a few weeks after commencement of the STEM Curricula in order to provide timely interventions on challenges which may have arisen from the implementation as well as management, environment and teaching and learning.

The research focused around four main aspects which were the general school information status, STEM Curricula intentions and implementation, delivery and attainment. The general school status looked at the institutional, departmental and teacher perceptions. The understanding, delivery and attainment of the Curricula concentrated on aspects within and across subjects and grade levels.

Objectives

a) To determine the existing status of the STEM Schools in terms of general school information
b) To assess teachers understanding of STEM Education Curriculum intentions and implementation
c) To evaluate how the STEM Education Curriculum is being delivered through lessons
d) To establish the attainment of the STEM Education Curriculum by the learners

2. Frame of Assessing Teaching and Learning in STEM Education

The frame of assessing teaching and learning in STEM Education is four-fold encompassing analysis of planning for lessons, delivery of lesson, progression of learners and the learning environment.

Conceptual Framework

In order to help learners, attain desirable skills and competencies, teachers need to have deeper understanding of the STEM Education Curriculum. To effectively achieve this there must be a refluxing relationship amongst teacher, learner and Curriculum, as shown in Figure 1, focusing on the learner and learning.

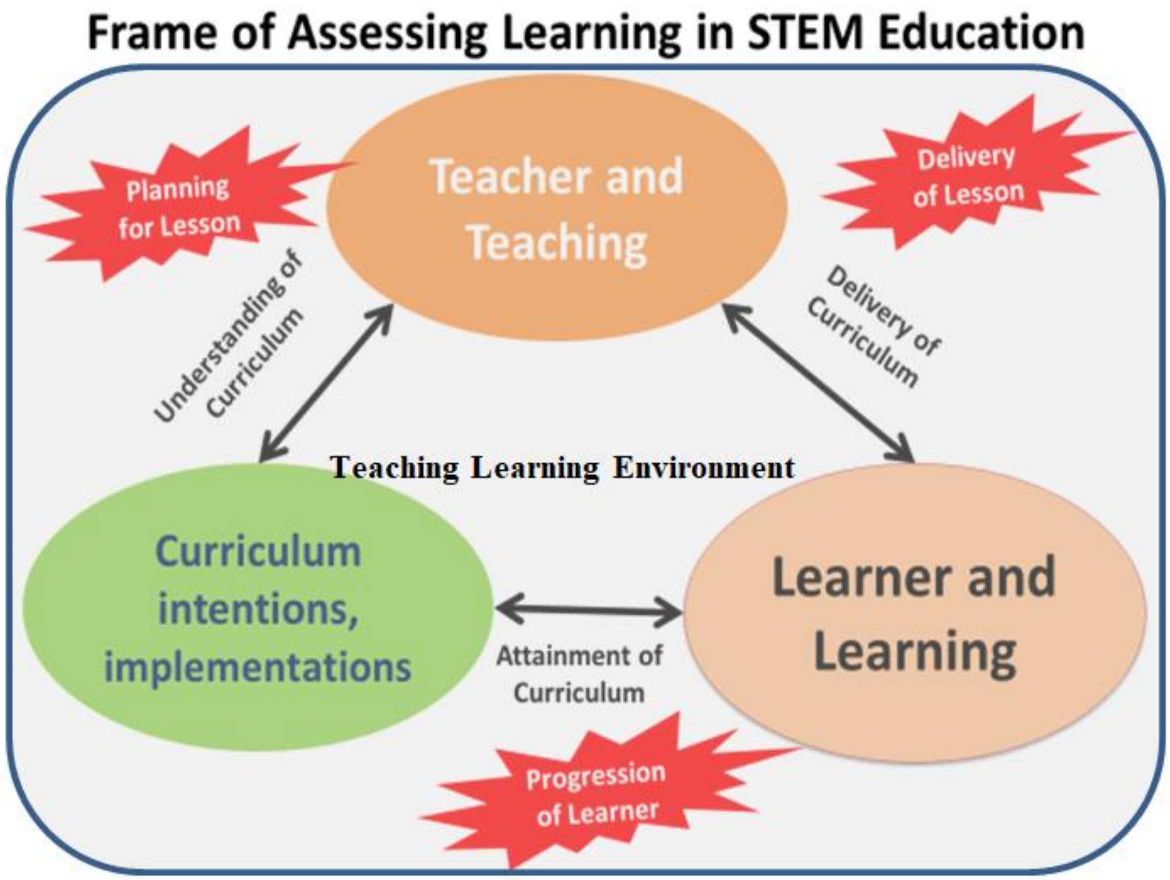


Figure 1: Conceptual Framework

STEM Education Curriculum Intentions and Implementation

The curriculum intentions represent the desired knowledge and competences that learners are to be exposed to and expected to attain. For this to be realized, the teacher as a facilitator for the learning process should interpret the curriculum in order to provide a teaching and learning environment that develops a holistic learner. In this regard, the STEM Education Curriculum intends to develop a learner who:

a) Is critical, creative and analytical
b) Relates thinking with real world situations
c) Is a problem solver
d) Is a responsible citizen

Therefore, for the effective implementation of the aforementioned intentions, the teacher needs to understand the curriculum.

2.1.1. Teacher and Teaching in STEM Education

The teacher, being the bridge between the curriculum and the learner, should be a facilitator in the process of attainment of the skills and competences. To meet the demands of the curriculum intent, the teacher needs to have adequate pedagogical content knowledge to help them plan for lessons which will bring out expected learning outcomes. To be effective, there is need for enhanced collegiality amongst teachers as they plan for lessons.

2.1.2. Learner and Learning in STEM Education

The focus of STEM Education is to produce a holistic learner who is creative, critical, analytical and innovative. This entails that in STEM learning learners will take centre stage in the learning process as advocated by constructivist tenets shown below:

a) Problem posing / situation [teacher]
b) Hypothesizing [learner]
c) Designing solutions [learner]
d) Presenting solutions [learner]
e) Confirmation of solution [learner and teacher]
f) Further problem posing [learner and teacher]

This learner driven approach to teaching and learning ensures that learners spend adequate time on various learning activities so that they develop the necessary skills and competences needed in modern day society.

Assessing Learning in STEM Education

STEM Education advocates the use of constructivist learning approaches that demands learners to take centre stage in the learning process. As part of the efforts to accommodate the implementation of STEM Education in STEM schools, the institutions need to create conducive learning environments in order to attain the intents of the curriculum. The support structures put in place to enhance STEM Learning will be assessed fourfold as follows: Learner progression, Delivery of lesson, planning for lesson and General school information analysis.

2.1.3. General School Information Analysis

The general school information will be analysed at institutional, departmental and teacher levels.

2.1.3.1. Institutional

At institutional level the data collected included; personal particulars for the head-teacher, STEM career pathways offered, the staff establishment, total enrolment of learners by gender, School-Based Continuing Professional Development (SBCPD) activities, availability of teaching and learning materials, strategies for assessing learning, number of classroom space as well as specialized rooms and their state.

2.1.3.2. Departmental

At departmental level the data collected encompassed; personal particulars for the head of department, staffing levels, teaching loads, subjects offered, School Based Continuing Professional Development (SBCPD) activities, sequence of activities after receipt of the STEM Education Curriculum, availability of teaching and learning materials, strategies for assessing learner progression and approaches used for teaching and learning.

2.1.3.3. Teacher

At individual teacher level, the data collected comprised; personal particulars, of the teacher, teaching load per week for STEM and Non-STEM, participation in SBCPD, availability of teaching and learning materials, participation in subject association & Junior Engineers, Technicians and Scientists (JETS) activities, strategies for assessing learner progression & approaches used for teaching and learning.

2.1.4. Planning for Lesson in STEM Education

Planning for lessons involved all activities, considerations and processes that the teacher or group of teachers undertook prior to lesson delivery. In this context, planning for lessons involved; lesson planning, resource materials consulted as well as teaching and learning aids preparation.

2.1.4.1. Lesson Planning in STEM Education

Lesson planning is prior-preparation that a teacher (individually and /or collaboratively) engages in. As the teachers plan, whether individually or collaboratively, they could use various lesson structures. In this context lesson plan requirements included lesson plan format, lesson plan rationale, lesson plan introduction, development as well as conclusion. Additionally, not only a plan for misconceptions that may arise and how they would be cleared was an aspect that should be included in STEM lessons but also a plan on how learning would be assessed in the learning process as well as a plan for board use.

2.1.4.2. Resource Materials in STEM Education

These are resources both teachers could use in STEM teaching and learning to support the understanding and implementation of curricula intentions. There are various teaching and learning resource materials that could be referred to before lesson delivery. In the perspective of this research, resource materials included print text and E-resources that were used to gather information for use in the teaching and learning process.

2.1.4.3. Teaching and Learning Aids Preparation in STEM Education

Teaching and learning aids preparation is an indispensable aspect of planning for lessons as it helps in supporting skill development and concept understanding. There are various teaching and learning aids that can be considered for use in lessons. However, in this context, teaching and learning aids planned and prepared for lessons referred to appropriate real objects that could make concepts relatable and understandable. The teaching and learning aids should not just be listed on the lesson plans but also a description of who would use them should also be provided.

2.1.5. Delivery of Lessons in STEM Education

In the Zambian case STEM Education Curriculum delivery is anchored on distinct constructivist approaches which entail that lesson activities should be learner-centred and include: teacher posing problem, learners hypothesizing, designing and presenting solutions, both teachers and learners confirming solutions and whenever possible pose further problems. This means that STEM teachers should endeavour to adapt lessons according to concept to be taught and learnt, subject and abilities of learners. In the context of this research, STEM Education Curriculum delivery did not only focus on lesson delivery which encompassed lesson introduction, development and conclusion but also utilization of workbook as well as teaching and learning aids.

2.1.5.1. Lesson Introduction, Development and Conclusion

In the delivery of lessons, it was imperative that learners get engaged purposefully in order to develop desired scientific skills. Therefore, the introduction, development and conclusion in the lesson needed to be planned with attainment of scientific skills in mind. The introduction of a lesson is very important as it sets the objectives of the lesson. It acts as a link to previously learnt material and sets stage for the new lesson. In the context of this research, the lesson introduction focused on its appropriateness to engage learners through the use of the key inquiry question, problem statement or scenario.

Lesson development is the main part in lesson. The entry into lesson development is a transition from a scenario, problem statement or key question in the introduction. In the lesson development stage both the teacher and the learner engage fully in learning activities. The learning activities should make learners actualise the key question or problem statement in the quest to achieve learning outcomes. The delivery of STEM Education Curriculum requires the use of constructivism approaches by teachers so that learners are given chance to explore, investigate explain and elaborate ideas. Learning in this way makes it easy for learners to develop appropriate literacy and life skills needed in the 21st Century. In the context of this research, the lesson development activities focused on teaching and learning strategies employed, flow of lesson activities and how the lesson ideas were consolidated.

Lesson conclusion marks the end of the lesson and brings out the main aspects on which the learning was based. It reminds learners of what they were engaged in during the teaching and learning process. It further connects the knowledge gained into real life applications. As a result, the ability of a teacher to notice and document both good practices and misconceptions arising from interactions become an integral part of the continuum of teachers' competences. In the context of this research, lesson conclusion focused on how the lesson aspects were summarized and how the lesson evaluation was done.

2.1.5.2. Learners workbook in STEM Education

The learners' workbook or activity book is a document that needed to have tasks in line with the concepts the learners were learning. For each lesson the layout of the learner's book could vary depending on what would be taught and learnt. In the workbook, the learner puts down the most important pieces of information on the new knowledge while the teacher gets the evidence of the thought organization of the learner in the learning process. As such the learner's workbook becomes a major resource for a learner to organize the thoughts and the learning progress in a coherent way for present and future references. In the context of STEM Education in Zambia, a Workbook**,** shall be referred to as a learner repository platform in either soft or hard copy format in which learners document their learning activities and experiences validated by the teacher in the process of teaching and learning with the view of attaining CCAT learner status. It should be noted that the bias of this workbook will be in line with the constructivist STEM ideals. The conceptual framework for STEM workbook is indicated in Figure 2

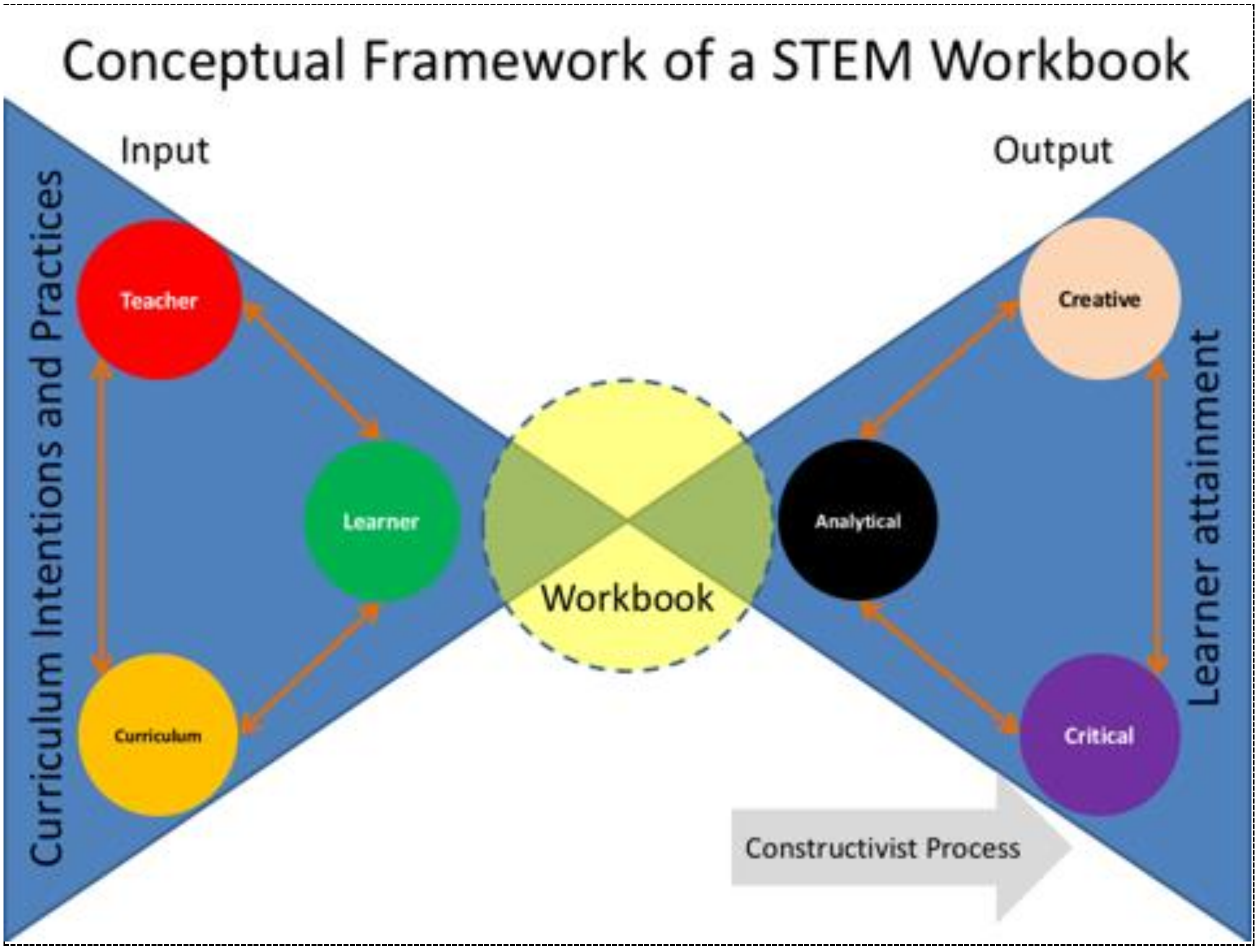


Figure 2: Conceptual Framework for STEM Education Workbook

The workbook is a means to attain curriculum intentions. To this effect the Workbooks in STEM Education is assessed as indicated in Figure 3

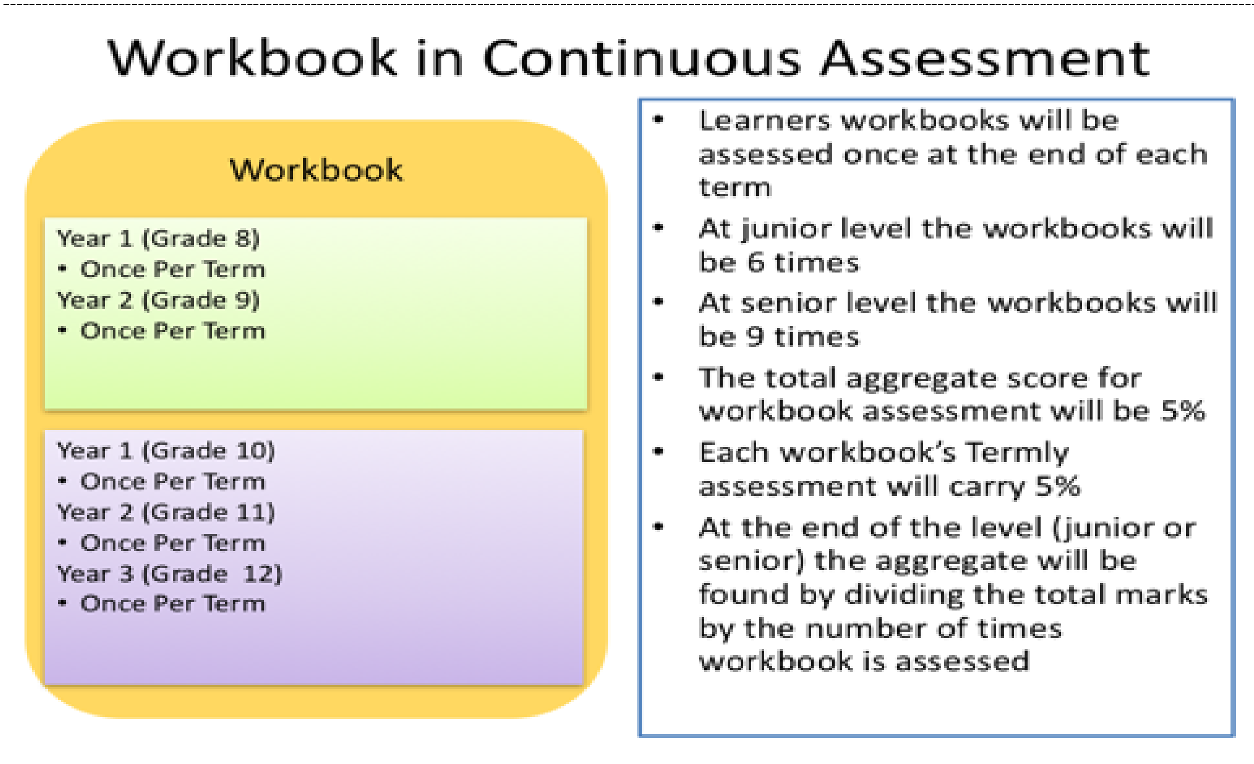


Figure 3: Workbook in Continuous Assessment

Table 1 indicates the detailed assessment of the workbook aspects and the weight allocations henceforth.

Table 1: Assessment of the workbook aspects

Aspect	**Detailed Description**	**Weight Allocation**
General management of the workbook	Presence of table of content, clear partitions	0.5
Practicals	Record of all practicals done	1
Assignments	Record of all Assignments done	1
Tests	Record of all tests done	1
Daily reflections	Record of all Daily reflections done	0.5
Research activities	Record of all Research activities done	1

The Workbooks should be Learner dependent, comprise of variety and diverse multiple view points on one concept, and have records of research-based learning activities such as assignments, tests as well as practical work. To ensure that the requirements of the workbook are realised the teachers and learners should perform specific roles as indicated in Appendix 1 In this research, learners' workbooks focused on whether work was written and how it was organised.

2.1.5.3. Teaching and Learning Aids Utilization in STEM Education

Teaching and learning aids utilization involved the appropriate use of teaching and learning materials by both teachers and learners to bring about understanding of concepts. Teaching aids needed to be used effectively during lessons. Teaching and Learning Aids (TLA) should be meaning and enhance learning as they provide visual representations that help to understand underlying concepts. To enhance effective teaching and learning, TLAs could either be prepared by learners, teachers or both. In this research, the focus was on whether or not the teaching and learning aids were utilized and who prescribed them.

2.1.6. Learner Progression in STEM Education

Learner progression is tracking the quality of acquisition of intended concepts, knowledge, skills and values. In STEM Education, learner progression refers to resolute sequencing of learning anticipations across developmental stages in the learning period. Learners would be tracked systematically in order to ensure that appropriate and timely interventions are instituted in real time. This should be done in three ways: school-based continuous assessment, research and scientific skill acquisition. In this context, learner progression anchored on the ability of learners to effectively do research, utilize workbooks, and acquire scientific skills.

2.1.6.1. Scientific Skills in STEM Education

As learners go through learning process, it is expected that they acquire certain educational attributes known as scientific skills, which take place as progressive attainment of learning outcome(s). It is from skills that we can attain a learner who is: critical, creative, analytical, innovative and an inventor. The Scientific skills conceptual framework is illustrated in Figure 4

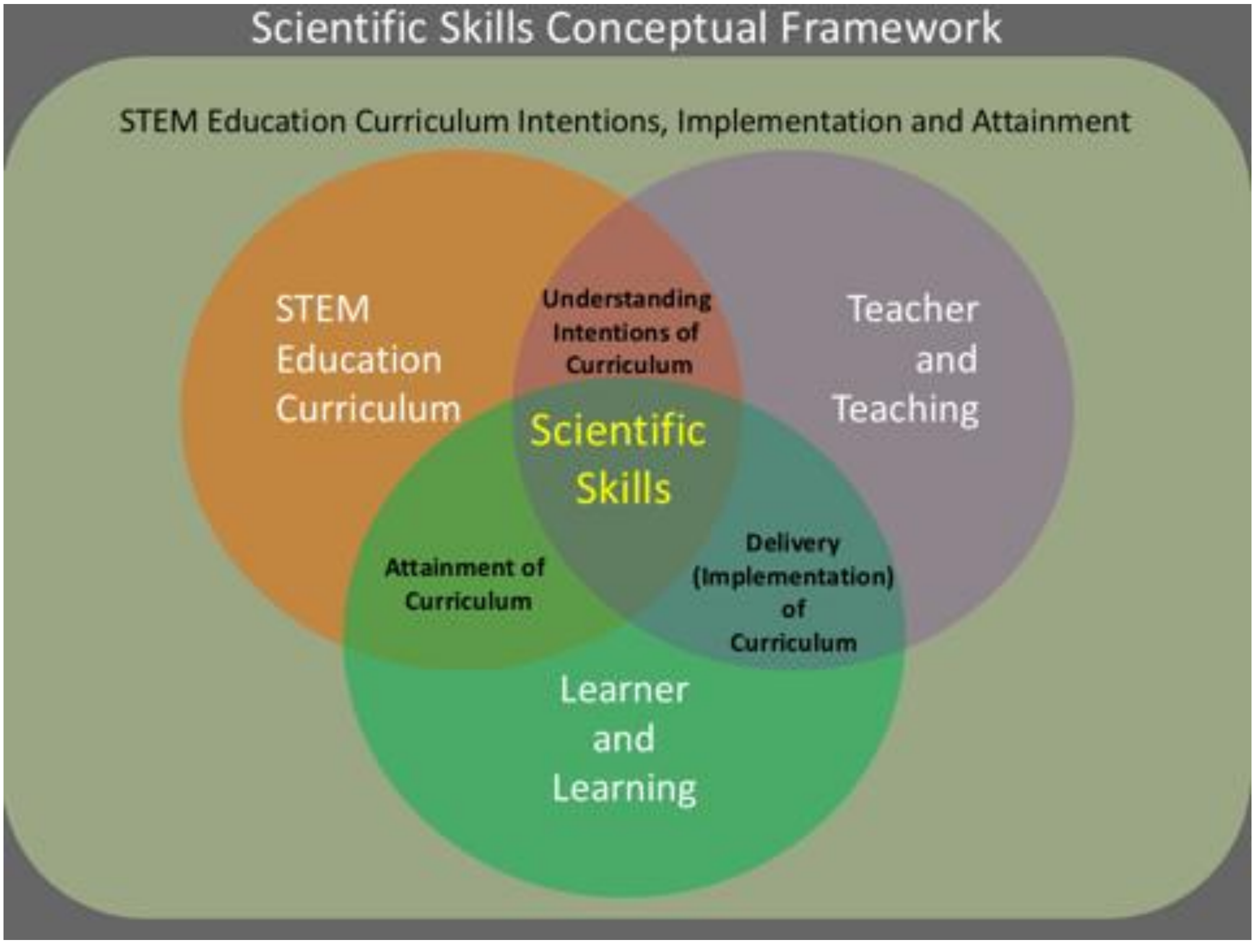


Figure 4: Scientific Skills Conceptual Framework

From the conceptual framework it is clear that Scientific Skills are a blend of the Curriculum intentions, teacher's understanding of the curriculum intentions, delivery of the curriculum and learners learning and attainment.

In STEM teaching and learning, the education attributes of focus included; Knowledge, Skills and Values outlined in broader categories as Acquisitive, Organizational, Manipulative, Creative and Communicative. The operational definitions and characteristics of these skills are:

2.1.6.2. Operational Definition of Scientific Skills in STEM Education

i. Acquisitive Skills

Acquisitive Skills are the ability to possess and accumulate intrinsic potential for eagerness to input information through sensory channels and proprioception in both passive and active ways in order to process it for making decisions about a situation or concept.

Characteristics of Acquisitive Skills

a) Listening
b) Observing

c) Searching
d) Inquiring
e) Investigating
f) Gathering data
g) Defining operationally
h) Researching
i) Formulating hypothesis

ii. Organizational Skills

Organisational Skills are the capacity to manage and stay focused on different tasks by using time, energy, mental strength and physical space effectively through forming structures within which order of doing tasks is clear and co-ordinated to achieve the desired outcomes.

Characteristics of Organisational Skills

a) Recording
b) Comparing
c) Contrasting
d) Classifying
e) Organizing
f) Outlining
g) Reviewing,
h) Evaluating
i) Analysing
j) Predicting
k) Inferring
l) Interpreting data

iii. Creative Skills

Creative Skills are the ability to perceive and think in an imaginative approach about physical occurrences to enable one to find hidden patterns and make connections among apparently discrete concepts in order to generate novel or unorthodox solutions and come up with something new to address the present and future challenges.

Characteristics of Creative Skills

a) Planning ahead
b) Designing
c) Inventing
d) Synthesizing
e) Formulating models
f) Sketching specimen and science apparatus

iv. Manipulative Skills

Manipulative Skills are the ability to physically interact with the materials or procedures to help in understanding of the underlying principles which might also involve some alterations in order to enhance the performance of equipment and functionality of processes

Characteristics of Manipulative Skills

a) Handling instruments and equipment
b) Demonstrating
c) Experimenting
d) Constructing
e) Calibrating
f) Measuring and using numbers
g) Controlling variables
h) Handling specimen correctly and carefully

v. Communicative Skills

Communicative Skills are the ability to effectively inquire and engage others, to obtain or disseminate vital information, coherently and clearly through the use of mutually understood symbols, signs and semiotic rules in order to make sense of what is intended.

Characteristics of Communicative Skills

a) Questioning
b) Discussing
c) Explaining
d) Reporting
e) Writing
f) Critiquing
g) Graphing
h) Teaching
i) Communicating

In STEM teaching and learning the skills in table 1 above were expected to be realized. In order to cultivate some of the skills, teachers needed to prepare and deliver lesson activities with a view to developing specific scientific skills.

2.1.6.3. Research in STEM Education

In the context of STEM Education in Zambia, research is a sandwich intermediate process in which the theories in STEM Education are transited into evidence-based products closer to prototype status as the learners go through the learning process. All the learners in STEM Education are expected to do research as minor and major respectively. Minor research implied small scale subject-based as desired by the subject specialist but guided by the implementation guidelines and guide for teaching and learning documents. Major research referred to graded full-scale research undertakings. Table 2 shows major researches to be undertaken in the STEM career pathways.

Table 2: Major Researches to be undertaken in the STEM Career Pathways

Pathways	Research
Agricultural Science STEM	Agricultural Science STEM Research
General STEM	General STEM - Mathematics Research
	General STEM - Biology Research
	General STEM - Chemistry Research
	General STEM - Physics Research
	General STEM - Computer Science Research
Technological STEM	Technological STEM - Graphic Communication Research
	Technological STEM - System Technology Research
	Technological STEM - Manufacturing Materials Research
Hospitality and Tourism STEM	Hospitality and Tourism STEM - Hospitality Research
	Hospitality and Tourism STEM - Tourism Research

In the major researches, learners will need to provide a research report, defend the research and make a product. The Research Conceptual Framework is as shown in Figure 5

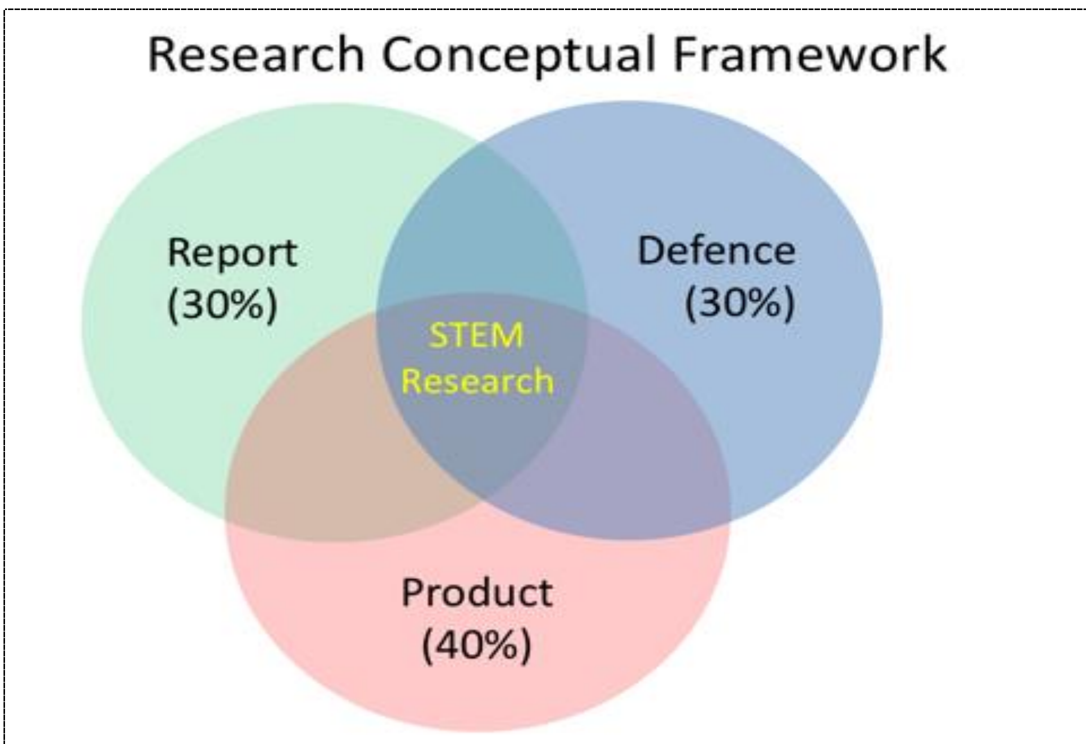


Figure 5: Research Conceptual Framework

i. Report in STEM Education Research

A research report in STEM is a document that contains basic aspects of the research project which include recorded data prepared after analyzing gathered information. It can also be considered as a condensed form or brief description of research work presented as a report. The layout of the report needs to be in a logical sequence showing; Title, Abstract, Introduction/Background, Objectives/Research Questions, Problem Statement, Literature Review, Methodology, Results/Findings, Conclusion, Recommendations, References. Other than that, this report needs to be typed in times new roman font, with 12 font size and line spacing of 1.5 and pages need to be numbered. The assessment of the research report will carry 30% of the 100% allocated for research. The research report is assessed from the viewpoint of the layout, appropriate aspect information and formatting assessment. The detailed weight allocations of the research report are as shown in Appendix 4

ii. Defense in STEM Education Research

Learners are supposed to defend their research through a viva voce presentation of evidence as research defense before a chosen committee or audience. The main purpose of this is for validation of work and input consideration for further improvement. During the research defense presentations assertiveness, understanding of subject matter, quality of power point presentation and time management are aspects to be taken into consideration. In STEM Education the assessment of the research defense will carry 30% of the 100% allocated for research. Table 3 shows the detailed descriptions and weight allocations that would be applicable when assessing defense in STEM Education research.

Table 3: Weight allocations assessing defense in STEM Education research

Aspect	Detailed description	Weight allocation
Assertiveness	Confidence, Self Esteem, Gestures, (Rapport with audience)	6
Understanding of subject matter	Communicating most important points of research work, ability to respond to questions raised	15
Quality of power point presentation	Coherent Power point form, Logical Flow	6
Time management	Coherent Power point form, Logical Flow	3
Total Weight		30

iii. Product in STEM Education Research

Other than the report, learners are expected to produce a research invention, innovation, artifact or manufactured good that emanates from a research process. In STEM Education the assessment of the research product will carry 40% of the 100% allocated for research. The detailed assessment of the aspects and weight allocations for consideration are shown in Table 4

Table 4: Assessment of the Research Product

Aspect	Detailed description	Weight allocation
Research work involved	Originality, innovativeness, use of appropriate materials (preferably largely local), value addition principle	12
Practical use	Operational, application in reality, environmental friendly, quality, cost effective	16
Operational principle (s)	How well Scientific, Technological, Engineering and Mathematical principles are applied and illustrated, user friendly, replicable, scalable	8
Suitability for commercialization	High potential for market entry, patentable, problem-solving	4
Total marks		40

In this context, the focus was on whether research lessons had commenced and how the research was being handled in STEM schools.

2.1.6.4. Continuous Assessment in STEM Education

In the context of STEM Continuous Assessment is the frequent evaluation of learners' learning performance and progress through out a prescribed course of study as distinct from examination. Continuous Assessment (CA) is an integral part of the STEM teaching and learning process. It helps to determine whether teaching and learning has taken place and outcomes have been achieved. Learners interact with their learning environment in which teachers operate as curriculum implementers. This interaction between the teachers and learners offers great opportunities for teachers to assess learning of their learners. To this effect, upon entry into a STEM school learner need to be continuously assessed by their teachers under the supervision of the head of department, deputy Head-teacher and the school Head-teacher. The essence of school-based assessment was to encourage both learners and the teachers to take responsibility of the learning and teaching and own them respectively. Learners will be assessed using assignments, practical work, tests, and workbook management. In STEM Education Continuous Assessment will comprise 65% of the School-Based Continuous Assessment (CA). The 65% is distributed as follows:

1. Assignments 30%
2. Practical Work 20%
3. Tests 10%
4. Workbook 5%

Figure 6 shows the details of the STEM Education CA conceptual framework.

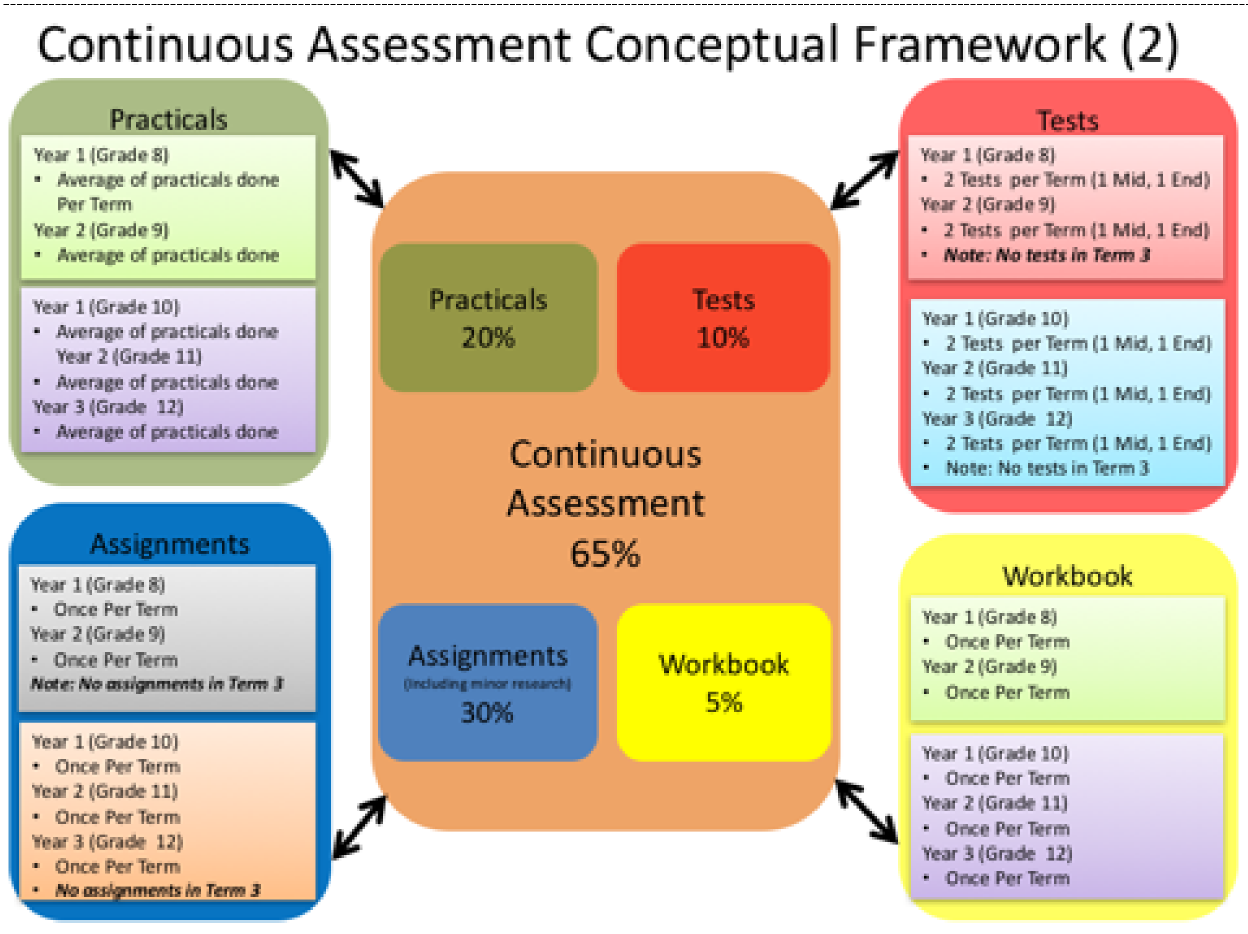


Figure 6: Continuous Assessment Conceptual Framework

The perspective of this research focused on how SBA was intended to be handled.

i. Tests in Continuous Assignment

In STEM Education, tests are written tasks intended to measure a learner's knowledge and skills. Learners are required to write these tests on hardcopy or softcopy. Additionally, some electronic tests will require to be answered and submitted in real time. The tests will carry 10 % of the 65 % marks allocated for CA. Figure 7 illustrates the distribution of the 10 % marks

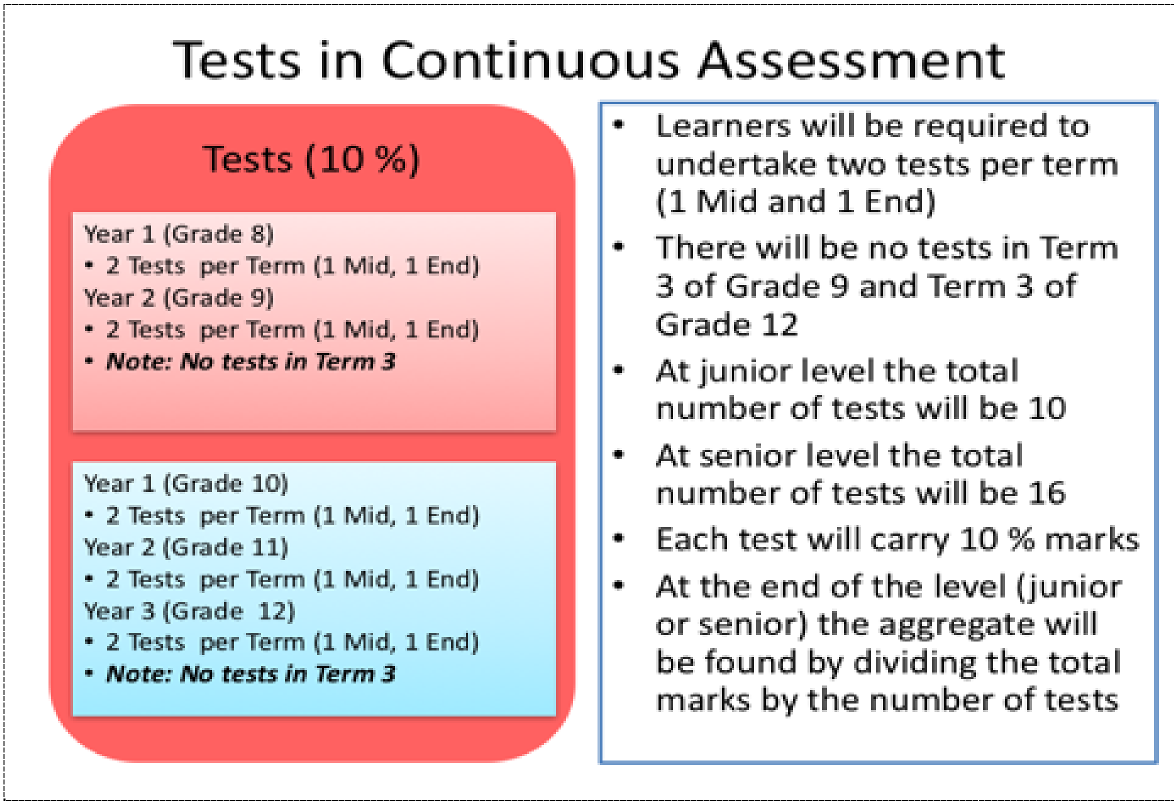


Figure 7: Test in Continuous Assessment

ii. Practical work in Continuous Assignment

Practical work is an important aspect of STEM Education. It includes a range of activities and is also used for a range of purposes, such as:

a) Illustrating a concept or idea to help students generate arguments from evidence in the process of knowledge construction

b) Developing practical, manipulative laboratory skills and learning how to use science equipment such as a microscope

c) Developing observational skills, such as the structure of a cell or observing changes on heating a chemical

d) Developing specific science enquiry skills, such as devising suitable tests or examining evidence critically (in science investigations)

e) Developing experience and understanding of ‘the nature of science’ and how scientists work.

Practical Work will carry 20 % of the 65 % marks allocated for CA. Figure 8 illustrates the assessment criterion of the 20 % marks

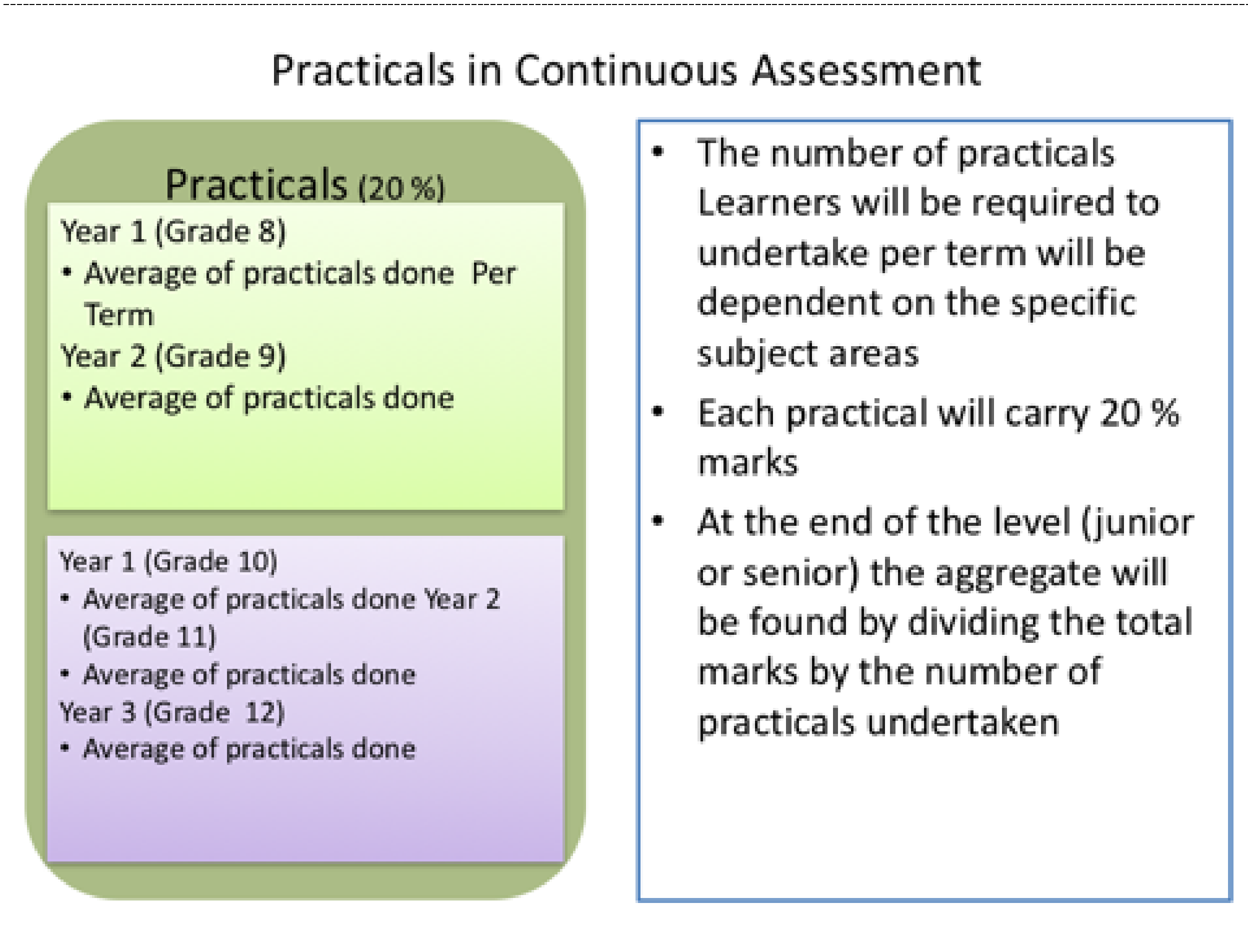


Figure 8: Practicals in Continuous Assessment

i. Assignments in Continuous Assignment

Assignments are tasks assigned by teachers to STEM students for completion outside regular class periods. Assignments are allocated to learners as part of the course of study at junior and senior levels. Each assignment will carry 10% marks except for the major assignment which will carry 20% of the 65 % marks allocated for CA. The Figure 9 illustrates assignments assessment criteria

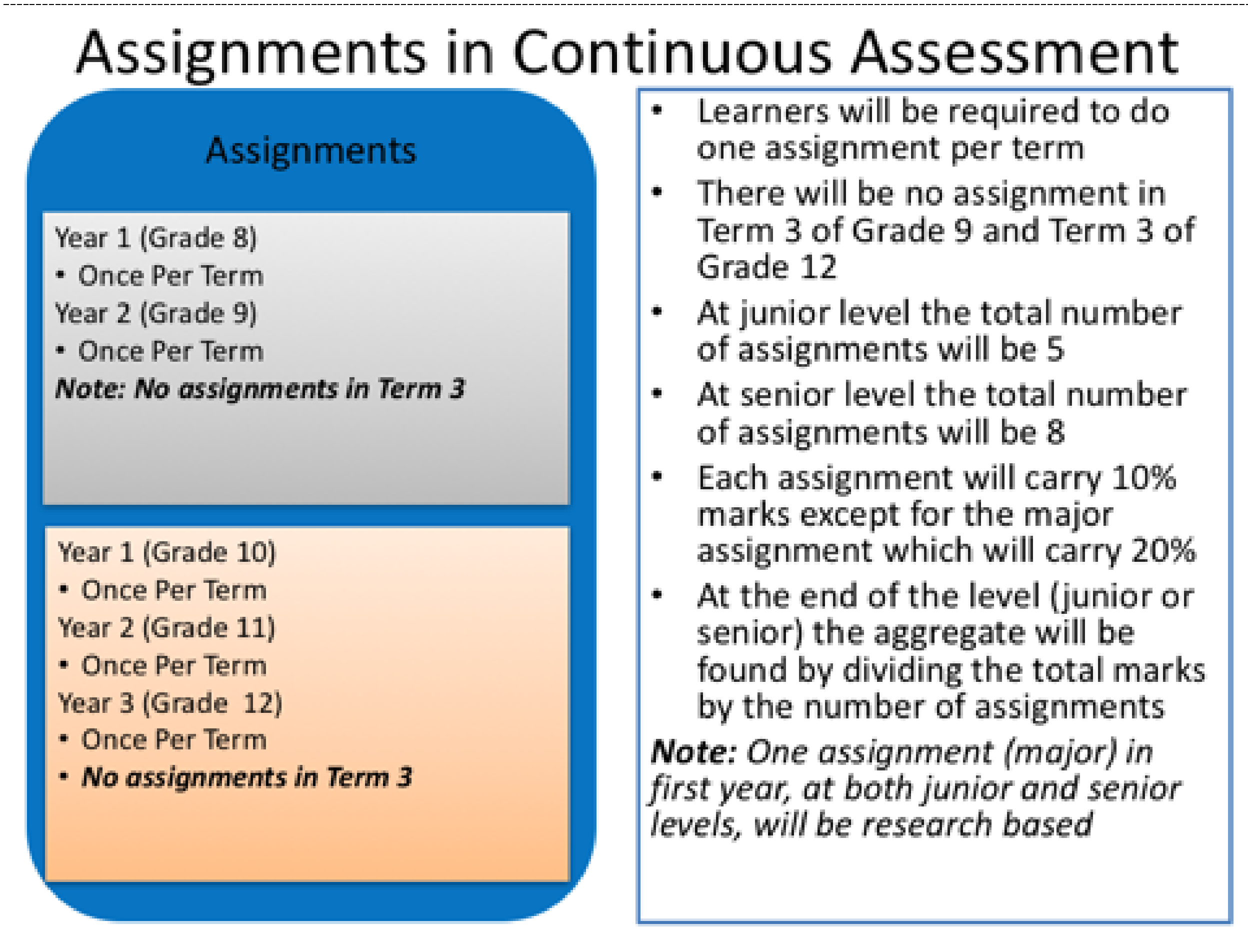


Figure 9: Assignment in Continuous Assessment

3. Methodology

The overall methodology in this study comprised of the research design, data collection process, research tools, targets and data analysis.

Research Design

In order to obtain numerical and in-depth information, the survey design used both qualitative and quantitative approaches. The research was designed taking into consideration the research objectives each mapped to an area of focus with the research tools and target respondents as shown in Figure10.

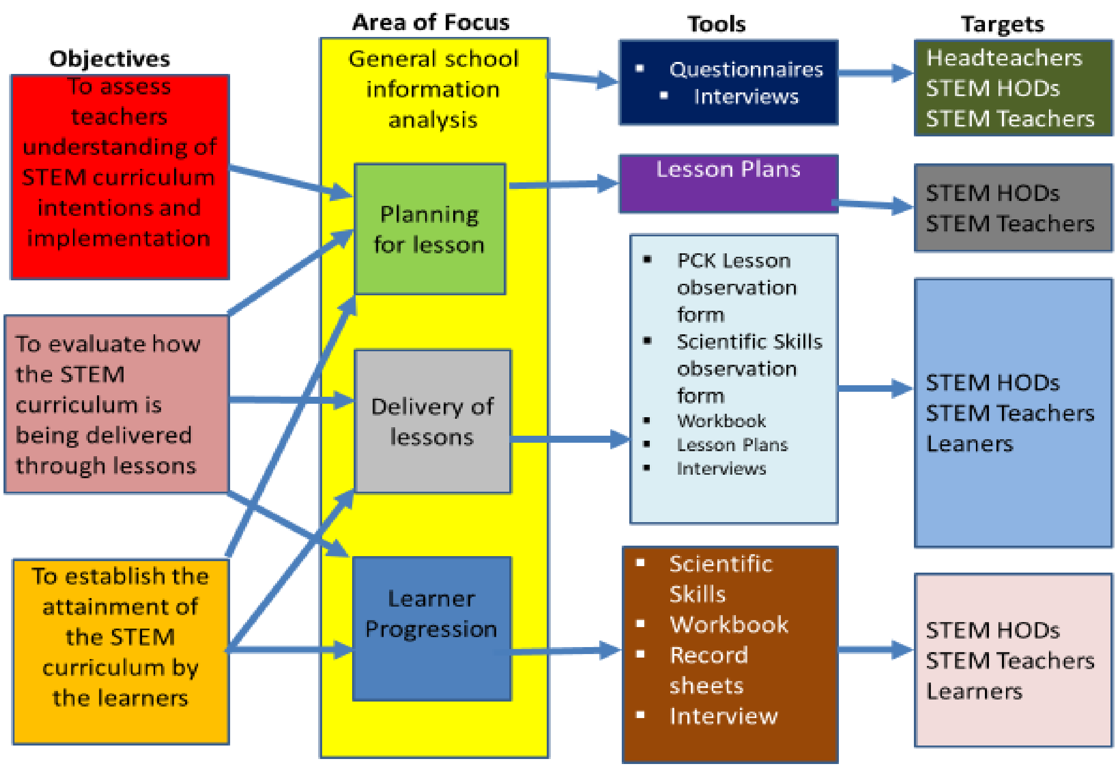


Figure 10: Research Design

The research design is summarized in Table 6.

Table 5: Summary of Research Design

	Area of Focus	Sub-theme area of focus	Approach / Tools	Target
1.	General school information analysis	a. Institutional b. Departmental c. Teacher	a. Questionnaires b. Interviews	a. Headteachers b. STEM HoDs c. STEM Teachers
2.	STEM Education Curriculum Intentions and Implementation	a. Planning for lesson b. Resource materials c. Teaching and learning aids preparation	a. Lesson Plans	a. STEM HoD b. Teachers
3.	STEM Education Curriculum Delivery	a. Delivery of lessons (Introduction, development and conclusion) b. Learners workbook c. Teaching and learning aids utilization	a. PCK Lesson observation form b. Scientific Skills observation form c. Workbook d. Interviews e. Video recordings	a. STEM HoDs b. STEM Teachers c. STEM Learners
4.	STEM Education Curriculum Attainment	Learner Progression a. Scientific skills b. Research c. School Based Assessment	a. Workbook b. Record sheets c. Interviews	a. STEM HoDs b. STEM Teachers c. STEM Learners

Research Tools and Targets

In this study the research approaches and tools used were questionnaires, interviews, lesson plans, PCK lesson observation forms, Scientific skills observation forms, workbook and record sheets whilst the targets were 15 Headteachers, 45 STEM HoDs, STEM subject teachers and stratified learners and lessons as shown in Figure 11.

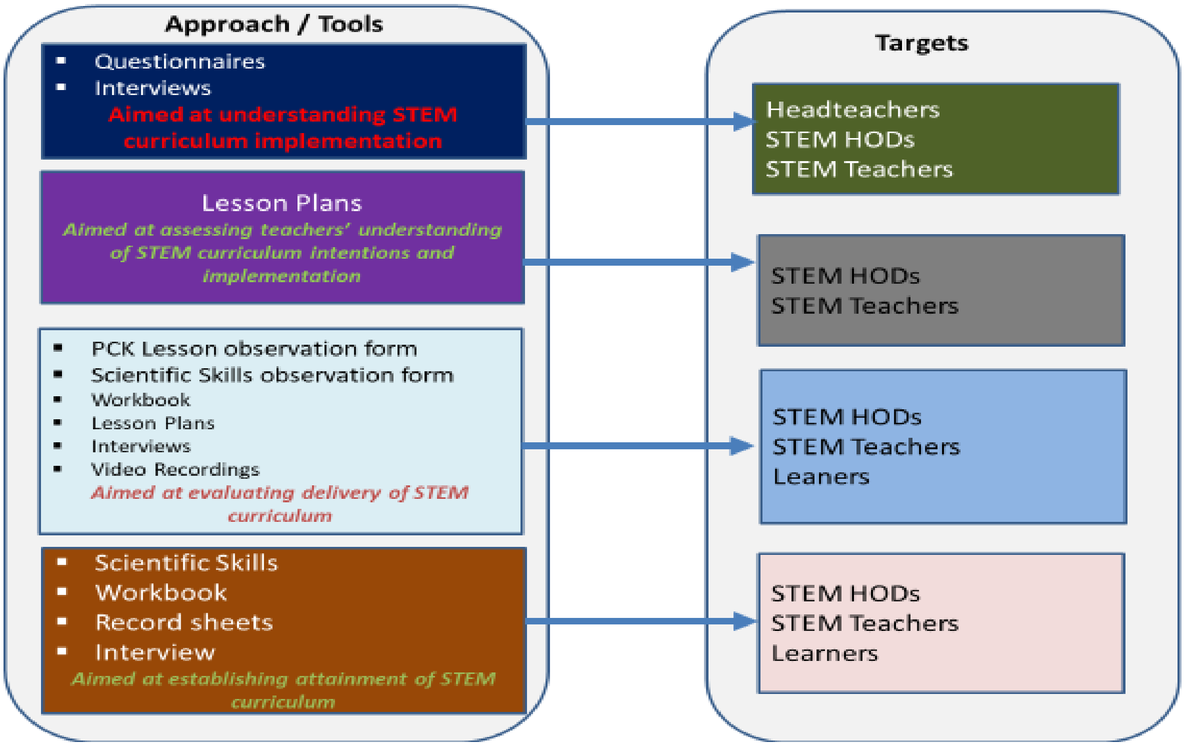


Figure 11: Research Tools and Targets

Data Collection Process

The research procedure involved physical visits to all the 15 STEM Schools and the following activities were sequentially done as shown in Table 6.

Table 6: Activities and Targets

Activity	Target
a. Debriefing on purpose of visit b. Distribution and filling in of Questionnaires c. Lesson Observation d. Interviews	a. Headteachers b. STEM HODs c. STEM subject teachers d. Learners

During the data collection process, the structured and semi-structured questionnaires were self-administered before the lessons were observed. This provided insights into how the STEM Education Curriculum was understood, managed and implemented. Additionally, learners were interviewed prior and after the lessons to assess the extent to which they were responding to learning using the STEM learning approaches. The lessons were observed in their natural settings in order to provide information and insights on how the STEM Education Curriculum was being implemented and delivered.

Data Analysis

Quantitative data was analysed using Microsoft Excel Package to generate graphs and tables whilst the qualitative data was analysed by coding data and synthesizing it into 4 major themes which were: General school information, STEM Education Curriculum intentions and implementation, STEM Education Curriculum delivery and STEM Education Curriculum attainment

3.1.1. General School Information

From the general school information analyses ideas on the length in service, qualification of administrators and STEM teachers, number of learners, subjects taught, how the condition of specialized rooms were affecting the planning and delivery of lessons as well as learner progression was obtained.

3.1.2. STEM Education - Curriculum Intentions and Implementation

Planning for lessons was used to obtain teachers effective understanding of curriculum intentions and implementation. The focus was on teachers' preparation of lessons as regards to curriculum outcome expectation, lesson planning, resource materials referred to as well as teaching and learning aids prepared for the lessons.

3.1.3. STEM Education - Curriculum Delivery

To understand the learning process the delivery of lessons involved analysis of the curriculum implementation and the focus was on the introduction, development and conclusion of the lesson, the learner's workbook, teaching and learning aids utilization with respect to the constructivist learning approaches.

3.1.4. STEM Education - Curriculum Attainment

Curriculum attainment involved analyses of data in order to show the progression of learners and in the learning process. The focus was on Scientific Skill acquisition demonstrated in lessons and research work. School-based continuous assessment aspects were also analysed to ascertain the level of attainment of the STEM Education Curriculum.

Limitations

The results of this research are an overview of STEM Education implementation in STEM Secondary Schools in Zambia. However, it is acknowledged that the research had limitations. Among the limitations were that, the research teams comprised a mixture of emerging researchers who had varied levels of experience which could have had an effect on the results. Another limitation was on data collection in which respondents withheld some information by either not completing parts of the questionnaire or not fully giving the necessary information during interviews. One reason could have been that they assumed the researchers were merely conducting routine monitoring from the Ministry of General Education. The other possible reason could have been that the respondents did not take the research exercise seriously as some of the researchers were in the recent past part of them in the teaching fraternity. The other limitation was in line with coding and analysis of qualitative data. The researchers were split into regions during data collection therefore, not all lessons were observed with the same lens and not all videos were properly recorded to ensure uniform coding of data.

This, therefore, means that, even though the results in general explain the situation in terms of STEM Education implementation, there were limitations and hence, the research has room for improvement.

4. Findings and Discussions

This chapter presents and discusses the results of the findings obtained from the assessment of the implementation of STEM Education in the 15 pilot schools countrywide. The presentations are in line with the following objectives;

a) To determine the existing status of the STEM Schools in terms of general school information
b) To assess teachers understanding of STEM Education Curriculum intentions and implementation
c) To evaluate how the STEM Education Curriculum is being delivered through lessons
d) To establish the attainment of the STEM Education Curriculum by the learners.

The research findings and discussions were presented using themes as shown in Table 7.

Table 7: Research Findings and Discussions

Area of Focus	**Sub-theme area of focus**
1. General school information analysis	a. Institutional b. Departmental c. Teacher
2. STEM Education Curriculum Intentions and Implementation	a. Planning for lesson b. Resource materials c. Teaching and learning aids preparation

Area of Focus	Sub-theme area of focus
3. STEM Education Curriculum Delivery	a. Delivery of lessons (Introduction, development and conclusion) b. Learners workbook c. Teaching and learning aids utilization
4. STEM Education Curriculum Attainment	Learner Progression a. Scientific skills b. Project and research c. School-Based Assessment

General School Information Analysis

For effective implementation of STEM Education, the general school information is one of the major contributing factors as this give us the bird's eye view of what and how processes are going on in the school. In this research, 15 STEM schools implementing STEM Education in Zambia were selected.

This section presents findings on the aspects affecting the implementation of STEM Education in the pilot schools in order to assess the management and implementation of the Transitional STEM Education Curriculum. The findings are presented from Institutional, Departmental and Teacher perspectives.

4.1.1. Findings and Discussions on the Institutional Status of the STEM Schools

All the 15 piloting STEM schools (five national and ten provincial) were monitored. It was observed that male Head teachers managed eight schools while female Head teachers managed the other seven. This represents an almost 50-50 percentage of management of STEM schools by gender. However, for National schools the percentage ratio was 80: 20 in favour of female Head teachers. Furthermore, 47 percent of the Head teachers have a second Degree (Masters) on top of the first-Degree qualifications. However, only 46.7 percent are trained in STEM related subjects. The majority of the Head teachers are trained in subjects other than Science, Mathematics and Technology. It was further noted that 60 percent had served as Head teachers for less than five years. Out of the fifteen schools, 47 percent were Boys only schools, 33 percent were Girls Only schools while 20 percent of the schools offered education to both Boys and Girls.

All National STEM schools were supposed to offer all the four STEM Curricula i.e. General, Agricultural, Technological and Hospitality & Tourism STEM Curricula. Provincial STEM schools are allowed to choose three out of the four Curricula, with General STEM Education Curriculum being mandatory. Figure 12 shows the distribution of STEM Curricula being offered at the STEM schools at both junior and senior levels while Table 8 shows the choice of STEM Education Curriculum Pathways by school.

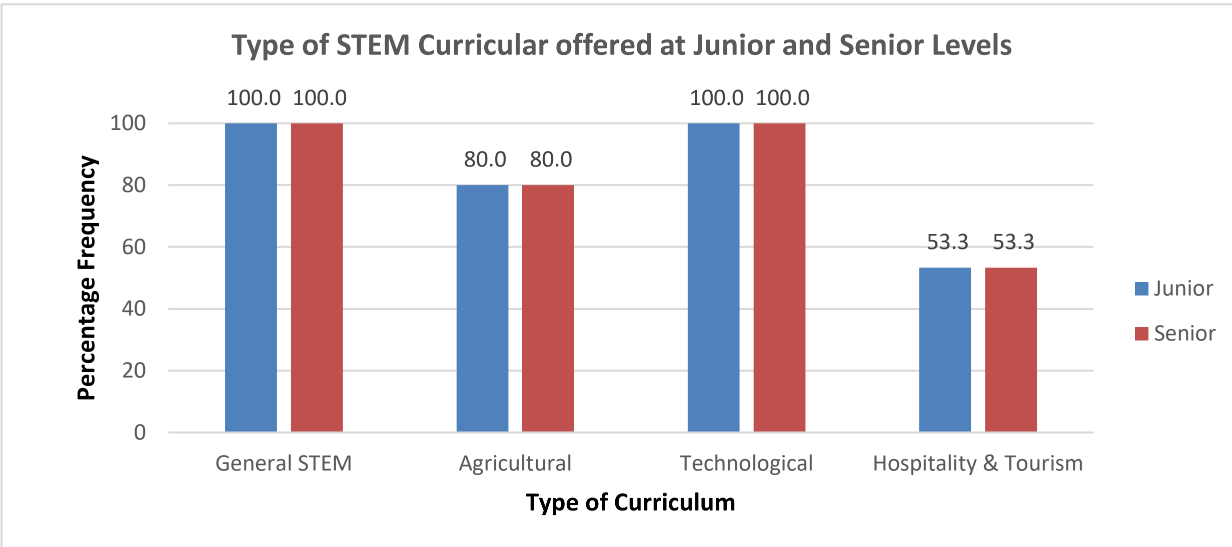


Figure 12: Type of STEM Curricula offered at Junior and Senior Levels

Table 8: Choice of STEM Education Curriculum Pathways by School

STEM School	**Junior STEM Education Curriculum Pathways**				**Senior STEM Education Curriculum Pathways**			
	General STEM	Agricultural	Technological	Hospitality & Tourism	General STEM	Agricultural	Technological	Hospitality & Tourism
Kapiri Girls National								
Serenje Boys Provincial								
Chiwala Boys Provincial								
Ndola Girls National								
Edgar Lungu National								
Musonda Girls Provincial								
David Kaunda National								
Rufunsa Girls Provincial								
Kenneth Kaunda Boys Provincial								
Mungwi Boys Provincial								
Solwezi Boys Provincial								
Hillcrest Boys National								
Niko Girls Provincial								
Kambule Boys Provincial								
Chizongwe Boys Provincial								

The revelation that the fifteen piloting STEM schools are managed by an almost 50-50 percentage of male and female Head teachers is encouraging and fosters the policy of equal gender participation in the management circles. In addition, this tends to encourage the female learners and female teachers alike that they, too, can rise to such heights and even beyond. However, a protracted observation on the National STEM Schools reveals an 80-20 percentage ratio in favour of females. Additionally, noteworthy taking is the fact that the Head teachers are sufficiently qualified to manage the STEM Schools. Furthermore, the 53 percent who are trained in subjects other than Science, Mathematics and Technology pose a healthy professional comparison on how the learning institutions are managed. So far, there was no remarkable distinction between female and male Head teachers in terms of efficiency and effectiveness. It will be an interesting research in the near future to determine how effectively and efficiently the Head teachers from such backgrounds managed their schools and whether this had an effect on the academic performance of their learners. The purpose of providing STEM Education to Boys only, Girls only and to Co-Education learners was to promote STEM Education under different conditions. Some sections of society believe that some learners perform well when they are of the same sex, while others believe that co-education promotes social tolerance, competition and collaboration among learners.

While National STEM schools offer all the four STEM curricula, Provincial STEM schools are allowed to choose three out of the four Curricula, with General STEM Education Curriculum being mandatory choice. It is clear that most of the Provincial schools prefer Technological and Agricultural STEM Curricula to Hospitality & Tourism (H & T). This could be attributed to the stereotyping preferences where Hospitality & Tourism was associated with girls' schools and Agricultural Science to boys' schools. Most of the classrooms in STEM schools were functional and in good condition. However, 8 percent of the classrooms were dilapidated and required rehabilitation, while 1.3 percent of them were under construction. Additionally, Figure 13 shows the availability of specialised rooms in STEM schools.

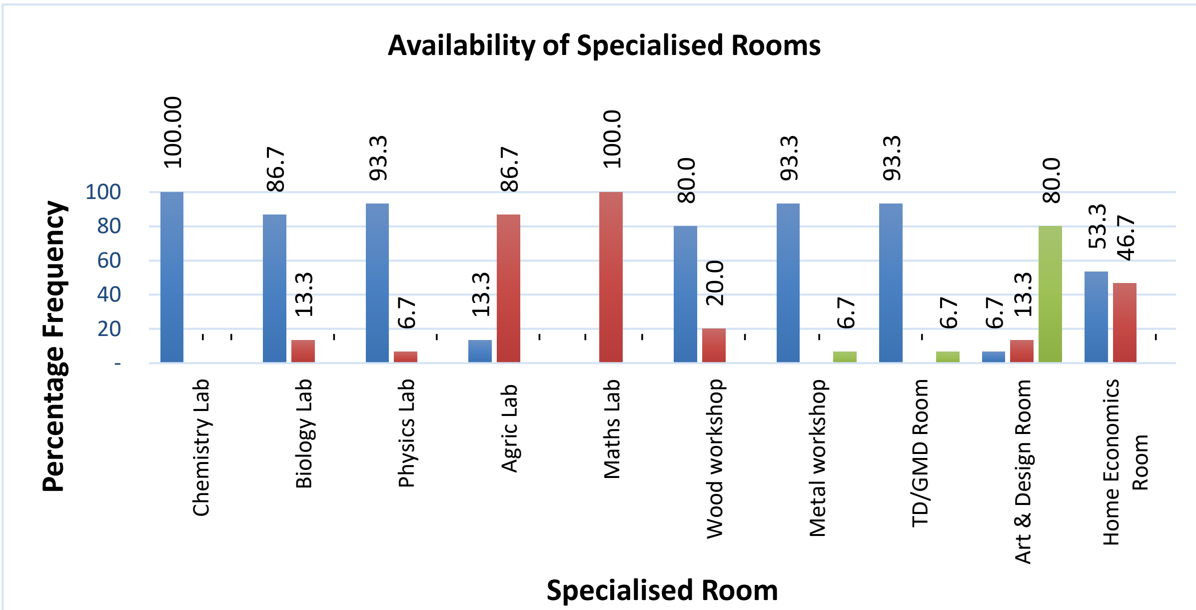


Figure 13: Availability of Specialised Rooms in STEM schools

While all schools reported that they had Chemistry Laboratories, Agricultural Science and Mathematics Laboratories were not available in most schools. In some schools, Head teachers indicated that they were not aware of such a thing as Mathematics Laboratory. In schools where these facilities were available, it was reported that the facilities were being used as intended.

Most of the schools reported that their classrooms were functional. However, it is incumbent upon the relevant authorities to ensure that the classrooms that are dilapidated are refurbished using various modes including the Preventive Maintenance System (PMS) where learners can be involved as part of the skills development and cost saving strategies. The unavailability of Agricultural Science and Mathematics laboratories in most schools is a hindrance to the effective implementation of STEM Education, especially for schools that opted for the Agricultural STEM Education Curriculum.

In 87 percent of the STEM schools, teaching of STEM Education commenced upon receiving the STEM Syllabi and other accompanying documents which guided the teachers on how to go about STEM Education delivery and assessment. Distribution of STEM Education Syllabi and Guidelines was done on 4th February, 2020. However, some schools (6.7%) reported that they commenced teaching immediately after the grace period given for late reporting of learners, while another 6.7 percent of the schools started teaching on other dates after receipt of the STEM Syllabi.

For the schools that commenced STEM teaching after receiving the STEM syllabi and other guidelines, the take-off was generally smooth and evidence of proper planning in line with the syllabi was observed. The documents that were dispatched together with the STEM Syllabi provided guidance on how to go about STEM Education delivery and assessment. However, those schools that reported commencement of teaching immediately after the grace period given for late reporting of learners had difficult time to readjust to the given guidelines. Moreover, they based teaching and assessment of learners on the 2013 syllabi and assessment plans, such as mandatory mid-term assessments.

The number of teachers in STEM Departments varied from school to school. However, the average

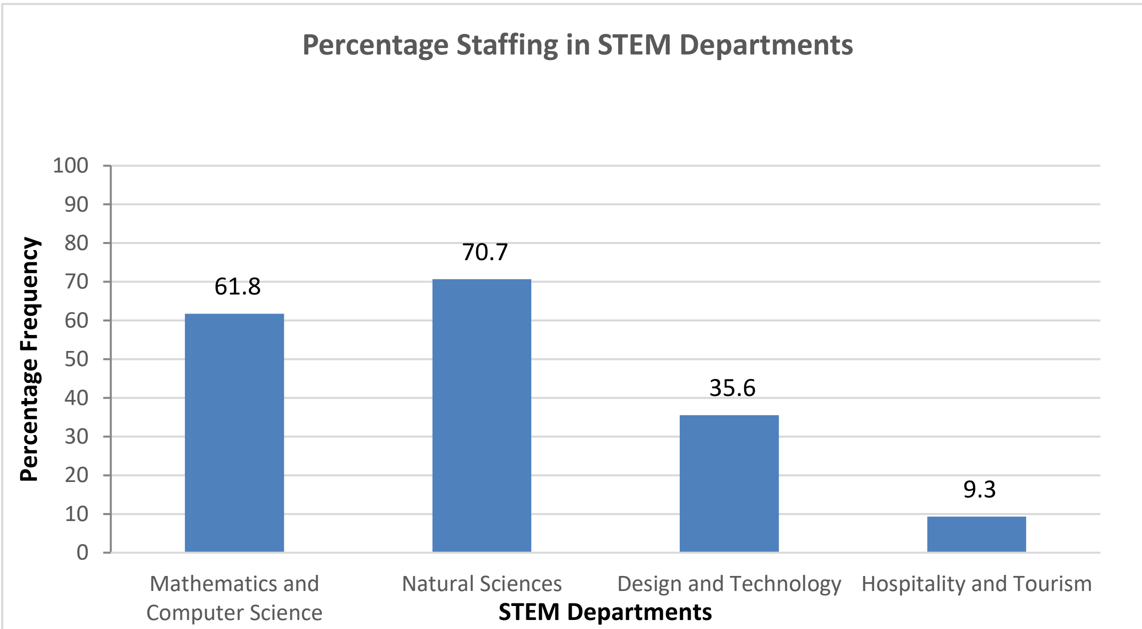


Figure 14: Percentage Staffing in STEM Departments

numbers in these Departments were as indicated in Figure14 while Figure 16 shows the percentage number of teachers teaching the various subjects in STEM schools.

The number of teachers in STEM Departments varies from school to school. The average numbers of teachers in most Departments are sufficient, especially in Mathematics and Natural Sciences. However, for the Design & Technology and Hospitality & Tourism Departments, the figures are not adequate. There is, therefore, need for additional staffing in these Departments, given the rising numbers of learners taking these subjects as shown in Tables 9 and 10.

The total number of learners in all STEM schools stood at 10, 920. Figure 15 gives the average distribution of the learners in each grade level per school. Additionally, one school reported a class of Advanced Levels (A-Levels) consisting of 48 learners.

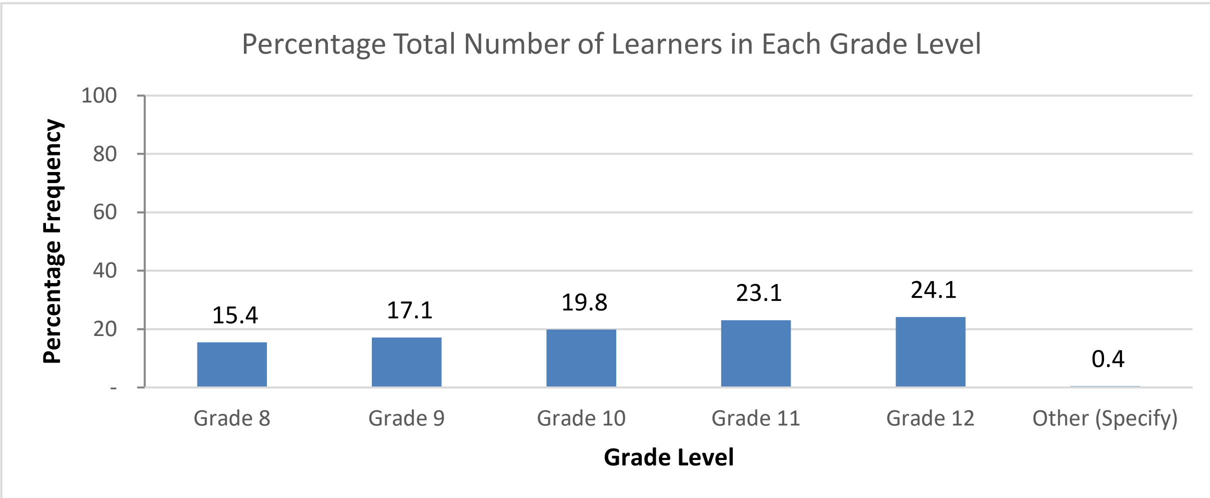


Figure 15: Percentage total number of learners in each grade level

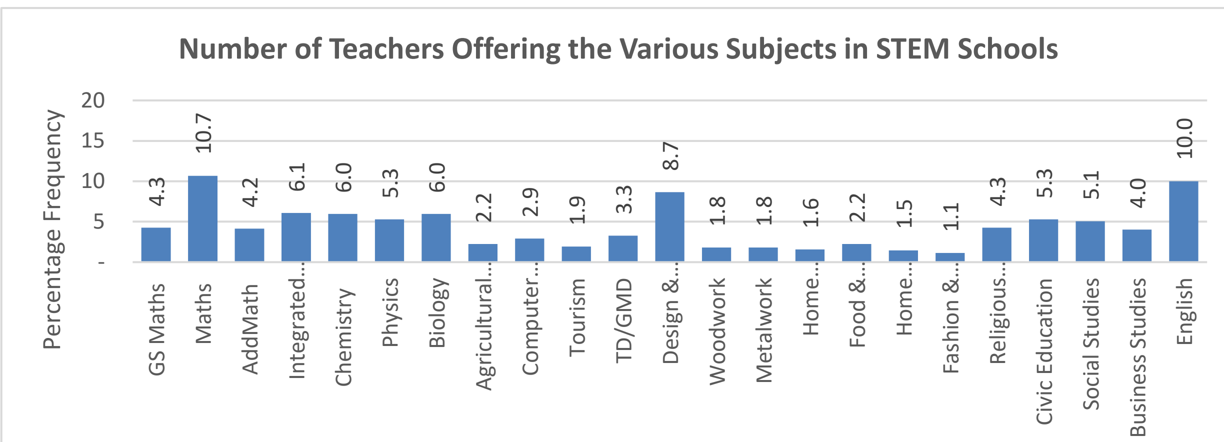


Figure 16: Number of Teachers Teaching the Various Subjects in STEM Schools

The total number of learners in all STEM schools stood at 10,920. The number of STEM learners varies from school to school. The percentage average number of learners taking STEM Education is 15.4 per school at Grade 8 level and 19.8 per school at Grade 10 level (See Figure 16). However, in some schools, the numbers are quite high while in others the numbers are low. Some schools did not achieve the expected targets of learner enrolment due to a variety of reasons. The most prevalent reason was inability to meet the user and boarding fees by some learners, especially at Grade 8 level. Hence, a number of them opted to go to nearby Day Schools where they were not required to pay for boarding and lodging.

On average, the numbers of learners taking various subjects both at junior and senior levels are as shown in Table 9 and Table 10.

Table 9: Average Number of Learners Taking the Each Subject at Junior Level

Subject	Percentage No. of Learners	Subject	Percentage No. of Learners
Maths	16.2	Hospitality & Tourism	1.5
Integrated Science	13.2	Design & Technology	7.4
Agricultural Science	3.1	Social Studies	12.8
Metal Work	2.2	Business Studies	10.5
Home Economics	1.8	Religious Education	12.6
Computer Science	5.7	English	12.8

Table 10: Average Number of Learners Taking Each Subject at Senior Level

Subject	Percentage No. of Learners	Subject	Percentage No. of Learners
General STEM Mathematics	2.1	Hospitality & Tourism	1.1
Mathematics	12.1	Home Economics	0.3
Add Maths	2.4	Food & Nutrition	1.1
Agricultural Science	1.9	Fashion & Fabrics	0.3
Chemistry	11.6	Home Management	0.6
Physics	11.6	Religious Education	6.8
Biology	12.0	Commerce	2.5
Computer Science	3.1	Principles of Accounts	2.5
Computer Studies	2.8	Civic Education	8.2
Design & Technology	7.7	English	11.7

On Co-Curricular activities, 87 percent of the schools indicated that they engaged in Clubs and Sporting activities, 80 percent of them in Preventive Maintenance and Production Unit, while 67 percent were involved in Subject Association activities. Additionally, 80 percent of the Head teachers reported that they often conducted and participated in Continuing Professional Development (CPD) activities aimed at enhancing teacher professional growth. The research reported that 73 percent sought further training in professional competencies, especially in Educational Leadership and Management. They also suggested that their staff required more of Assessment Skills (93%) and Pedagogical Skills (87%) in order for them to deliver STEM Education to the learners.

Schools engaging in Co-Curricular activities, especially CPD activities should be encouraged as these activities enhance pedagogical content knowledge among teachers. Furthermore, when engaged in productive Co-Curricular activities, learners can develop their skills in various aspects.

One way of engaging learners is by giving them tasks to solve environmental problems or improve the infrastructure through rehabilitation activities.

Head teachers indicated that they required further training in Educational Leadership and Management in order to enhance their managerial and supervisory skills, especially when it comes to aligning external evaluation of schools with internal school evaluation, and improving data handling skills of the schools they managed. Head teachers need to maximise the use of information and meet information needs at that level and to monitor key outcomes of the STEM Education system through learner assessment, teacher appraisal, and school evaluation. In addition, for their staff, they suggested that they acquire skills in assessment of learning and in pedagogy. With these skills, the teachers would be able to provide STEM Education effectively to the learners.

All the 15 schools reported that they had desktop computers as part of the ICT equipment available in schools. Eighty percent indicated that they also had printers while 67 percent had Liquid Crystal Display (LCD) Projectors in their possession. However, 87 percent said these equipment and other Teaching and Learning Materials (TLMs) were insufficient in quantities and efficiency. Despite the insufficiency, learners accessed the TLMs. To this effect, all the schools requested for more and a variety of TLMs to be provided for both teachers and learners. Among these TLMs requested for was a reliable supply of internet service for research and communication.

STEM Education is predominantly research-based. As such, learners are required to use ICT gadgets quite often as they look for solutions for their tasks and to prepare presentation of their solutions. However, the ICT equipment found in most schools, are inadequate and, in some instances, non-operational. It is commonplace to find as many as five learners surrounding one desktop computer working on a task. Some learners reported that they found it difficult to work on the computers in their Computer laboratories because most of the time these facilities were constantly occupied by other learners. They suggested that it would be of great help to alleviate the shortages had they allowed them to bring gadgets such as laptops, tablets and even smart phones. Moreover, most of the desktop computers found in these schools are refurbished second hand machines with out-dated or backward operating systems and applications. Some peripherals such as printers do not work. Some teachers also reported challenges to access the LCD projectors in schools as it was most of the time monopolised by some Departments. Not having steady and reliable internet connectivity was also another challenge faced in almost all STEM schools that was hindering research and communication. STEM Education recommends the extensive use of these equipment and materials by both teachers and learners in the preparation and learning processes. Other teaching and learning materials are also in short supply hence, the schools' quest for provision of more TLMs.

Figure 17 shows the types of assessment that schools had planned to administer to their learners and what had been executed to-date. It was observed that some schools (87%) had subjected the STEM learners to the non-STEM type of mid-term format of assessment. Since the STEM schools were using a dual Curriculum (STEM and non-STEM) there was a bias in planning which was

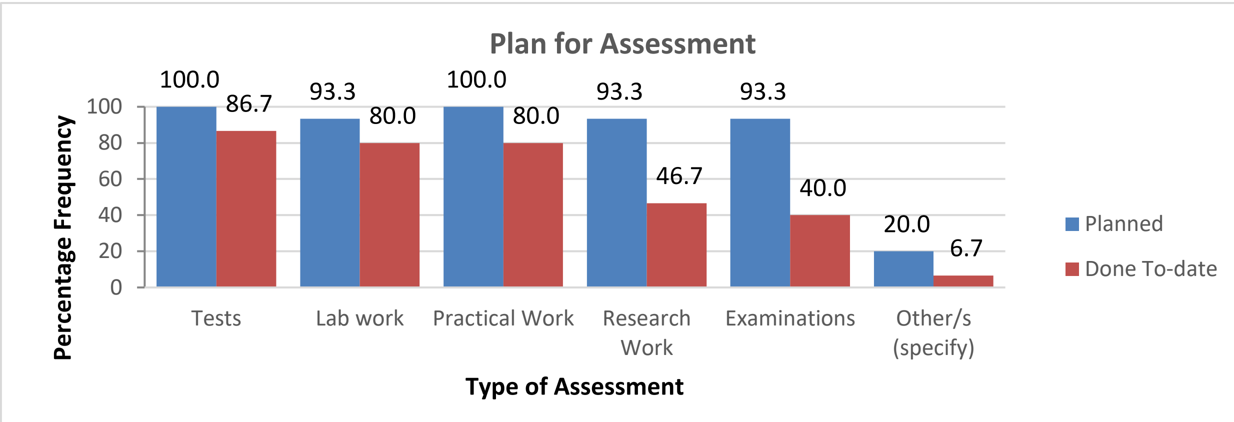


Figure 17: Plan for Assessment

tilted towards non-STEM. As a result, it was discovered that at the time of research, 93% of the schools had planned to conduct examinations of which 40% had subjected the STEM learners to this kind of assessment.

Some schools reported that they had administered tests and examinations to learners. Learners had barely settled down in the STEM Education provision. The format of learning by STEM learners is quite different from that experienced by non-STEM learners. Therefore, subjecting the STEM learners to the mid-term tests and examinations like other non-STEM learners in the schools was rather too early and premature. It also indicates that the teachers in these schools did not pay attention to the instructions sent together with the Syllabi regarding assessment of STEM learners. The results so obtained from those tests were misleading and might misdirect the interventions for learner outcomes. Evaluation and assessment frameworks can only have value if they lead to the improvement of classroom practice and learner attainment.

The Head teachers, when asked to suggest reasons for the low learner performance in Science, Mathematics and Technology subjects 80 percent attributed the low performance of the learners in these subjects to the fact that the learners did not study enough. Sixty percent and 47 percent indicated that this was due to lack of quality learning materials and that the teachers were not using appropriate methodologies respectively. It is the responsibility of the heads of the learning institutions to ensure that learners receive quality learning through the provision of appropriate learner support. This could be in form of teaching and learning equipment and materials as well as effective management of the learning process. Furthermore, management should develop the strategies for quality-assuring the assessments and monitoring learner performance.

4.1.2. Findings and Discussions on the Departmental Status of STEM Schools

Forty-six Heads of Department (HoDs) from the Natural Sciences (32.6%), Mathematics (32.6%) and Practical Subjects (34.8%) participated in the monitoring exercise. Among these, 80 percent were male while the remaining 20 percent were female. As observed under Institutional analysis, the majority (52.5%) of the HoDs have been performing their duties as HoDs at their current institutions for less than 5 years. The results showed that none of the HoDs had trained in ICT related subjects (see Figure 18).

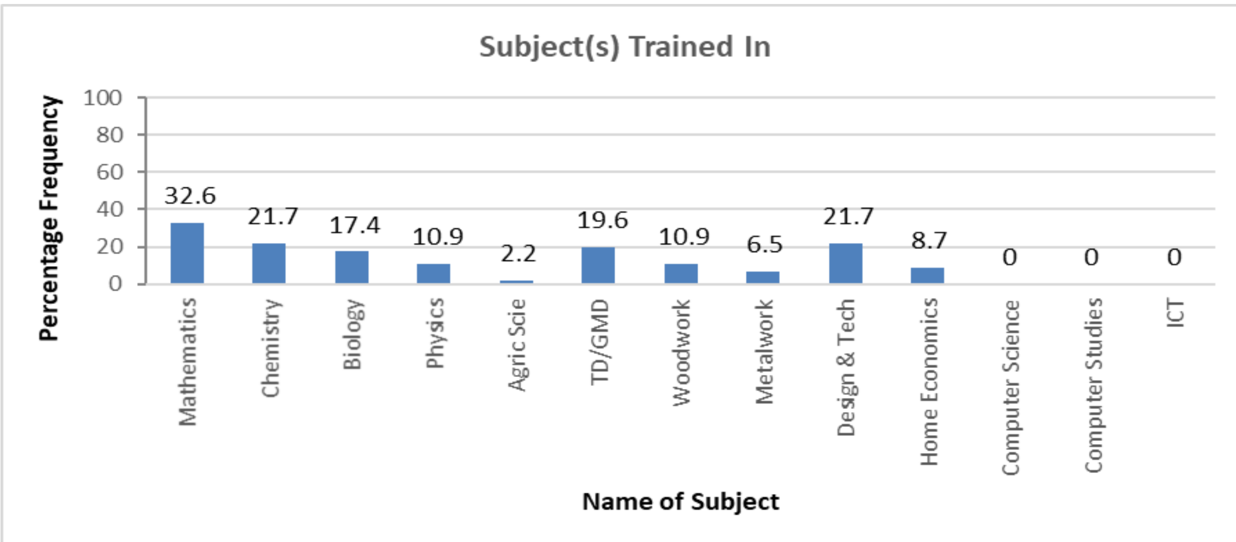


Figure 18: Subjects Trained in by HODs

The revelation that only 20 percent of the HoDs were female shows an imbalance in the headship of the Departments. There is, therefore, need to encourage female leadership in such capacities as well. Most of the HoDs are youthful as can be observed from the length of service at their institutions. This implies that the HODs are trainable and capable of transforming the education system in the institutions they operate. The fact that among the HoDs there was no one trained in ICT is a source of concern. This is chiefly because Computer Science and Computer Studies teachers are "annexed" to the Mathematics Department, whose HoD is basically a Mathematics teacher. Therefore, the authorities should seriously consider creating a stand-alone Department for Computer Sciences.

The minimum qualifications for most of the HoDs were first Degree (87%), with 4 percent of them having acquired Master's Degree in STEM subjects. This creates a stable platform for effective implementation and delivery of STEM Education. HoDs have a mandate to ensure that teachers in their Departments improve their own practice by identifying their strengths and weaknesses for further professional development. It also involves helping teachers learn about, reflect on, and adjust their teaching methodologies to STEM practices. Additionally, HoDs are supposed to hold teachers in their Departments accountable for their performance in enhancing learner attainment.

The Competencies they required most were Pedagogical Skills (59%), Educational Leadership and Management (50%) and Assessment Skills (46%), in that order as shown in Figure 19. Hence, their quest for further training in Pedagogical Skills, Educational Leadership and Management and Assessment Skills is appropriate as this will foster the HODs' managerial and supervisory skills. They will also entrench content knowledge.

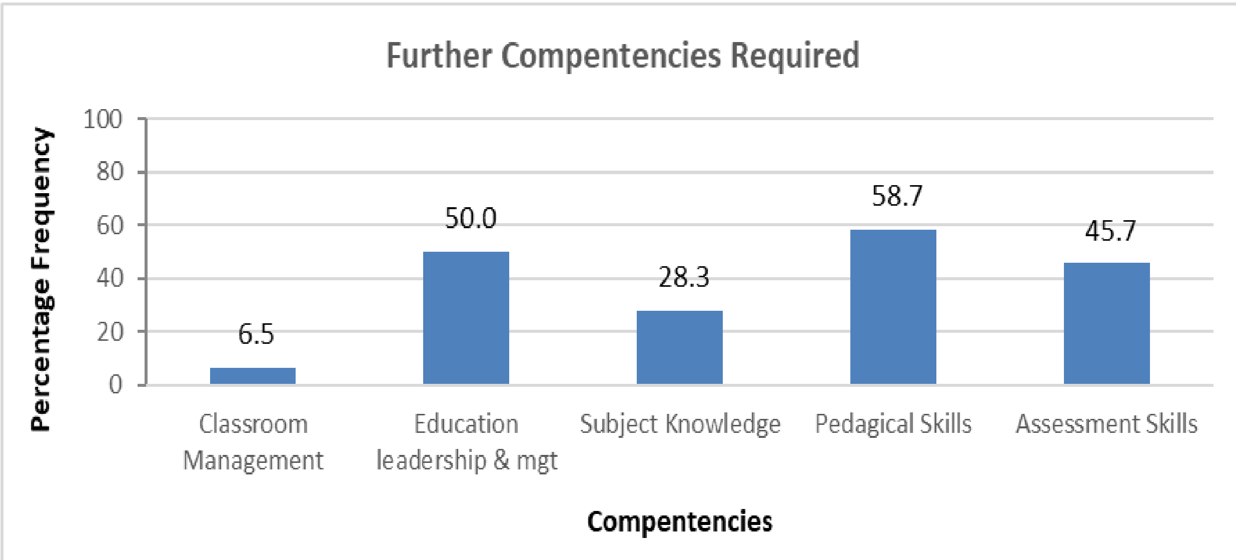


Figure 19: Further Competencies Required

HODs play an important role in managing Departments. Nonetheless, with the high teaching loads that they have, the supervisory role may be jeopardised. The average number of periods taught by most of the HoDs per week was between 15 and 24. However, 28 percent of the HoDs indicated that they taught more than 24 periods per week. They further reported that the average number of teachers required in each Department was nine. Currently there were, on average, eight teachers in each Department although in certain extreme cases there were as many as 17 teachers while in others as few as one member. There was inadequate teaching staff in the departments as evidenced by high teaching loads in comparison with the required number of teachers as per establishment. In a number of schools, there was critical shortage of teachers. Therefore, there is need to address the teacher imbalance.

Depending on the combination of the STEM Curricula offered at a school, learners took various subjects as shown in Figures 20 and 21.

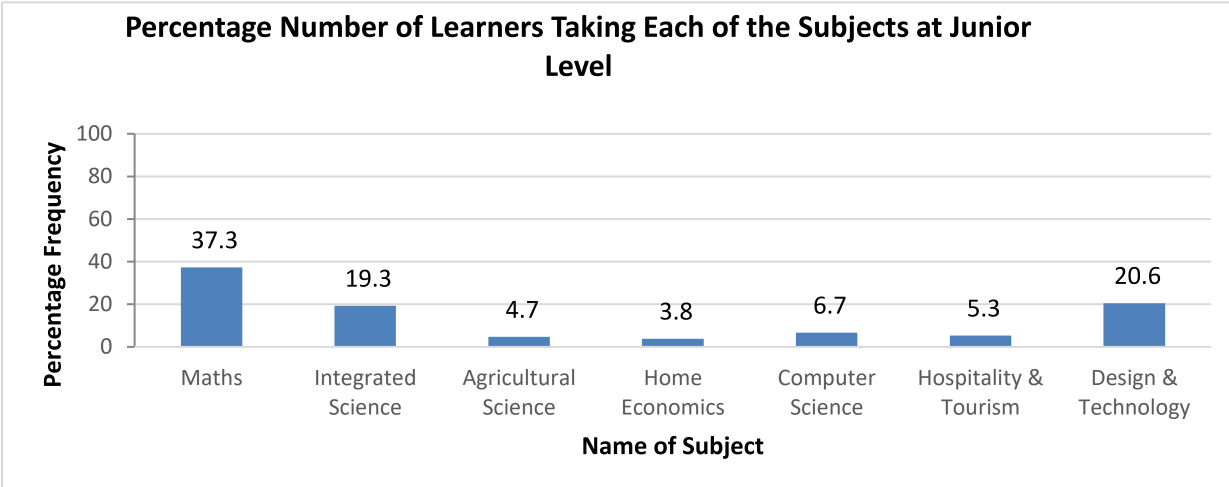


Figure 20: Percentage Number of learners taking Each of the Subjects at Junior Level

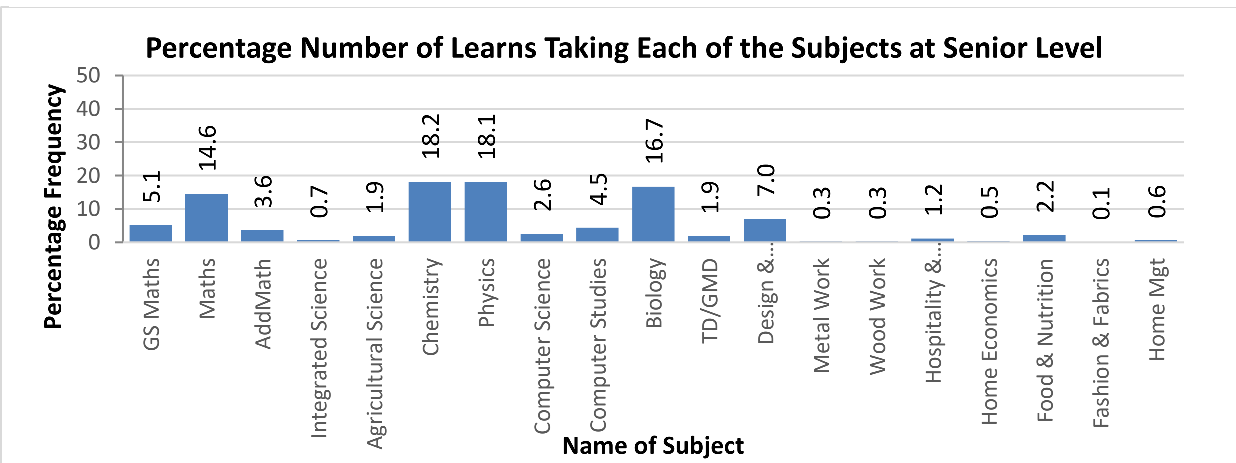


Figure 21: Percentage Number of Learns Taking Each of the Subjects at Senior Level

Depending on the combination of the STEM Curricula offered at a school, learners took various subjects. It was incumbent upon HODs to market their subjects and attract learners to these subjects. This could be done through sensitisation of learners on career prospects and assessment schemes involved.

All the 46 HODs who were monitored confirmed having received the STEM Syllabi and other documents providing guidelines on how to proceed with the implementation of STEM Education delivery. Out of these, 91 percent reported that they downloaded the documents upon receipt, 85 percent held a Departmental meeting while 46 percent held a CPD meeting to discuss strategies for effective and efficient delivery of the content. STEM teaching essentially commenced upon receipt of the STEM Syllabi as reported by 61 percent of the HODs. However, in some schools, teaching started immediately after the 'grace period' for learners who reported late for school. This was before the STEM Syllabi were dispatched. Figure 22 shows responses from HODs on when STEM teaching commenced.

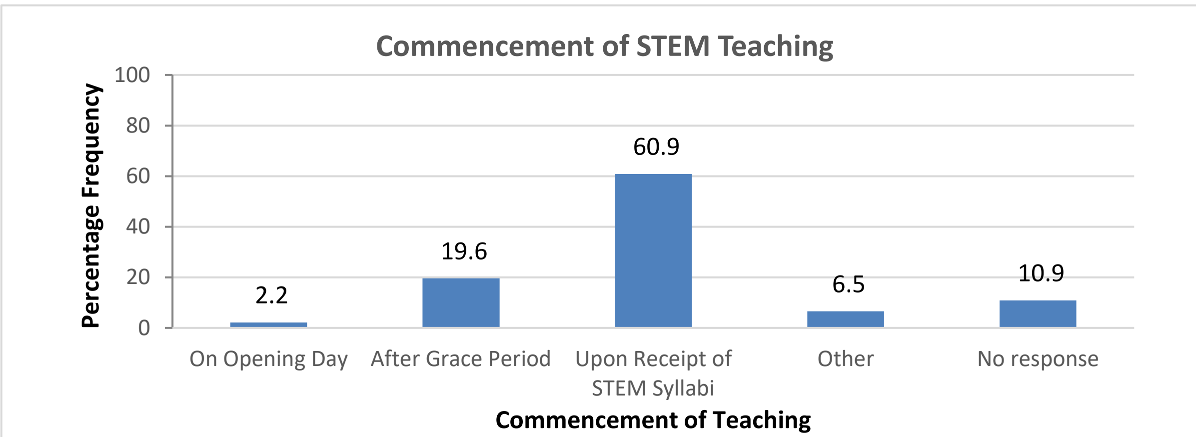


Figure 22: Commencement of STEM Teaching

As indicated under institutional, commencement of STEM teaching required receipt of the STEM Syllabi and other documents providing guidelines on how to proceed with the implementation of STEM Education delivery. The Departments that held Departmental meetings and CPD meetings to discuss strategies for effective and efficient delivery of the content did as was instructed in the accompanying memo by the Director – National Science Centre. However, it was evident in those schools where STEM teaching started earlier before receiving the guidelines that many teachers were using the 2013 Curriculum hence their styles of teaching were contrary to those espoused in the guidelines.

Most of the Departments (74%) indicated that they collaboratively planned for lessons, and that they observed each other's lessons as a way of improving their own teaching strategies, though not often. The HoDs also reported that their learners' response to STEM Education was positive and that they were affirmative to the STEM teaching approaches used by the teachers.

Teachers' understanding of the curriculum they were supposed to deliver is very important. This is because their knowledge of the curriculum and textbook content is applied in lesson implementation and achievement of curriculum goals. Since textbooks expand the content of the curriculum, teachers should use the textbooks to plan and teach lessons. Despite the current absence of STEM textbooks collaborative planning would help teachers use the available ones effectively. As teachers engage themselves in intensive study of teaching and learning materials and collaboratively planning for lessons, they tend to grow professional skills in terms of pedagogy, assessment as well as subject content. It was assumed that the learner-centred teaching approaches that the teachers were employing based on the tenets of constructivism, made the learners to develop positive attitudes towards STEM education.

The most common format of lesson documentation was by way of lesson plans. This was attested by 78 percent of the HoDs. However, only 59 percent of the HoDs confirmed that they submitted these documented lessons to National Science Centre. There was need for HoDs to document and share good practices arising from effective planning, delivery of lessons and progression of learners on the Learning Management Platform. To this effect internal quality assurance should be strengthened within the school for effective documentation, publication and improvement.

Figure 23 indicates HoDs' responses on whether learners were using Workbooks to record their learning tasks and research work. Forty-eight percent indicated that learners used the Workbooks for the purposes. Learners should be encouraged to document their tasks, solutions and research activities in their workbooks. This can show growth of the learners' attainment of the curriculum concepts and progression of research work. They can also use their notes raised during their research to explain how they are using scientific and mathematical concepts to come up with their solutions.

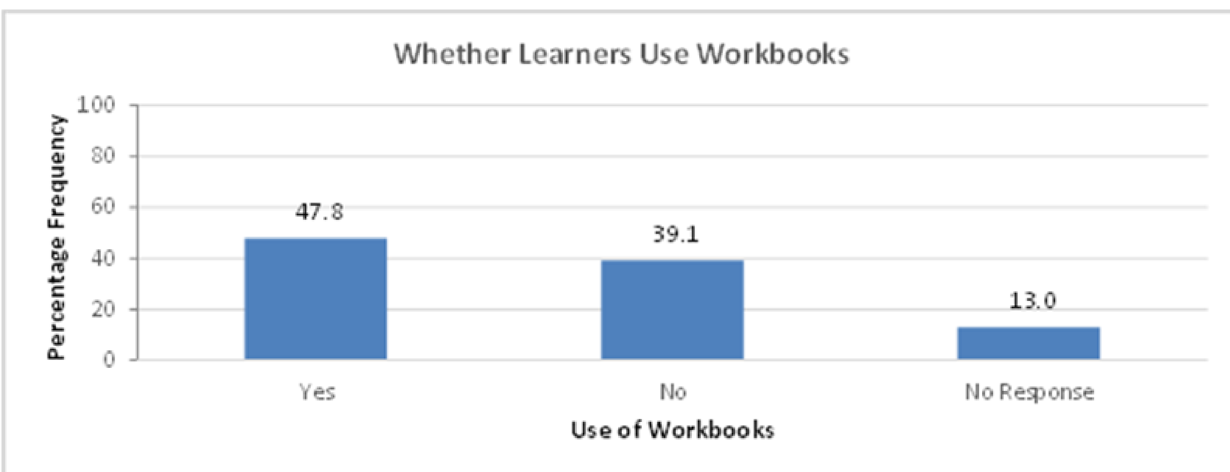


Figure 23: Whether Learners Use Workbooks

The HoDs indicated that they frequently conducted and participated in CPD activities in their Departments and the common activities included School-Based CPD (SBCPD), attested by 78 percent, Departmental workshops (65.2%) and Subject Association activities (50%). To this effect, they suggested that acquiring pedagogical and assessment skills would assist them to deliver lessons to their learners more effectively (see Figure 24). While initial teacher training develops one's subject content and teaching skills, it is insufficient in itself to prepare teachers for everyday teaching. This, coupled with many deficiencies in the knowledge base of the incoming teacher trainees in the areas of content, pedagogy, skills and competencies, makes it difficult for teachers to plan and deliver quality lessons. Hence engagement in any forms of CPD including SBCPD activities can help in building teachers' confidence in lesson delivery, identifying of challenges and good practices, equipping teachers with appropriate & current trends in lesson delivery and fostering co-operation amongst teachers for easy sharing of information and practices.

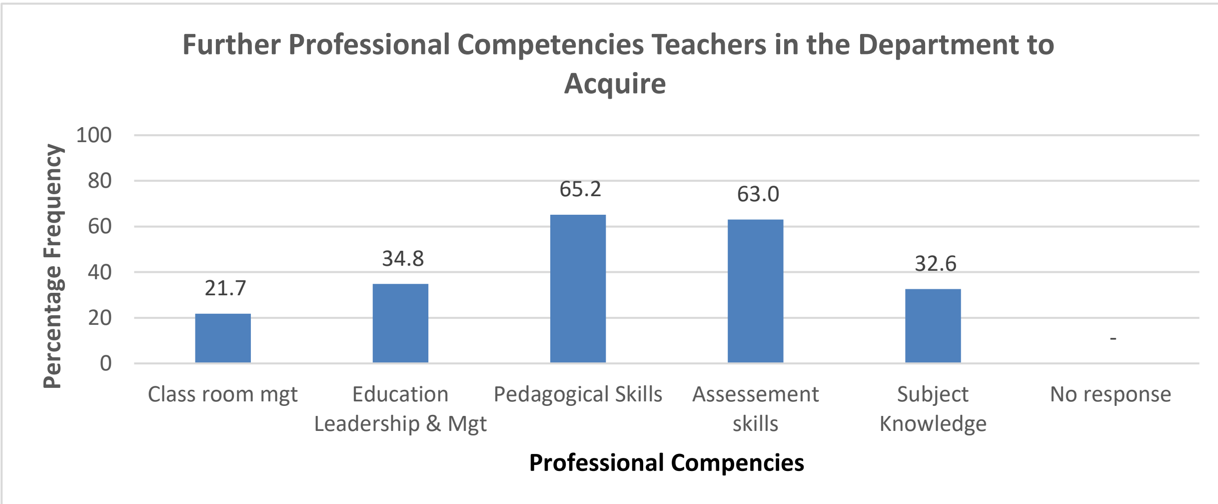


Figure 24: Further Professional Competencies Teachers in the Department to Acquire

According to the HoDs, the common forms of ICT equipment mostly used by teachers in their Departments are desktop computers, printers and laptops as shown in Table 11. However, the HODs reported that these and other TLMs were in short supply. They, therefore, implored the Government to provide more TLMs such as sewing machines, laptops, computers, assorted apparatus, internet connectivity and textbooks for effective and efficient delivery of STEM lessons to learners.

Table 11: Percentage Frequency of Availability of ICT Equipment in Departments

ICT Equipment	Desktops	Laptops	Printers	Scanners	RISOs	Binding	LCD Projectors	Overhead Projectors
Percentage Frequency	71.7	43.5	47.8	26.1	30.4	6.5	32.6	15.2

Schools should strive to equip Departments with the necessary ICT equipment and other teaching and learning materials. This will help the teachers in the Departments to plan adequately and deliver lessons effectively and efficiently. Deliberate plans to stock the Departments with the materials should be devised.

Figure 25 shows the modalities that Departments in various STEM schools put in place for assessing learning and what sort of assessment had been done to-date.

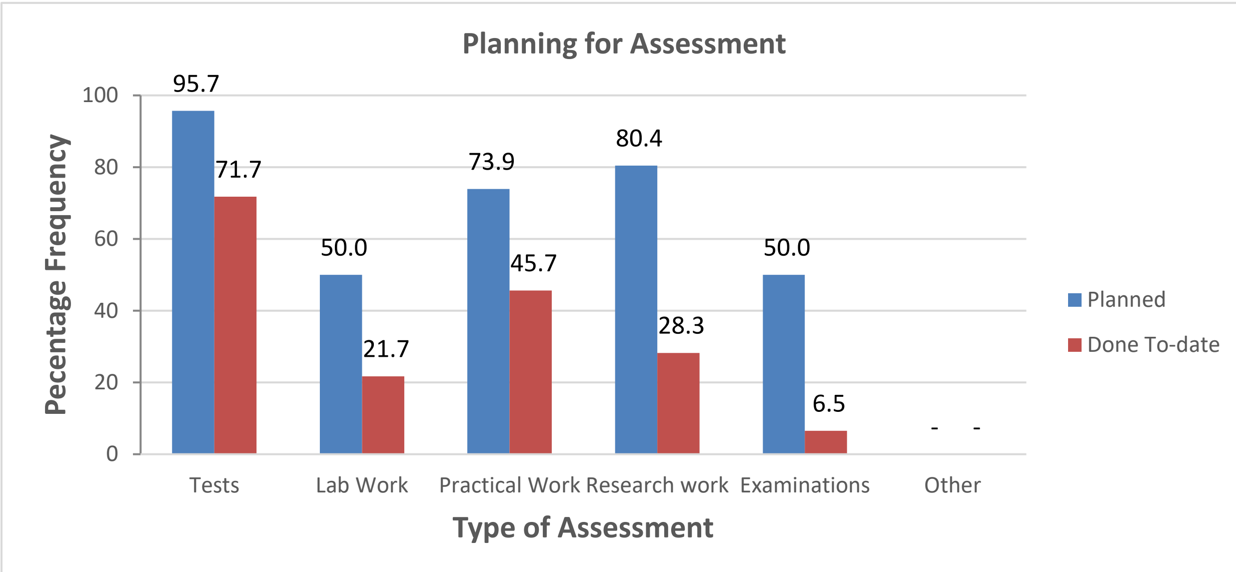


Figure 25: Planning for Assessment

Almost all Departments planned to administer tests and research work activities to their learners in the course of the Term. It was observed that most Departments (72%) administered tests barely two weeks after commencement of STEM teaching. Furthermore, the HODs reiterated that lack of quality learning materials, the fact that learners do not study enough and poor staffing were some of the reasons why some learners failed to learn and make progress in education (see Figure 26).

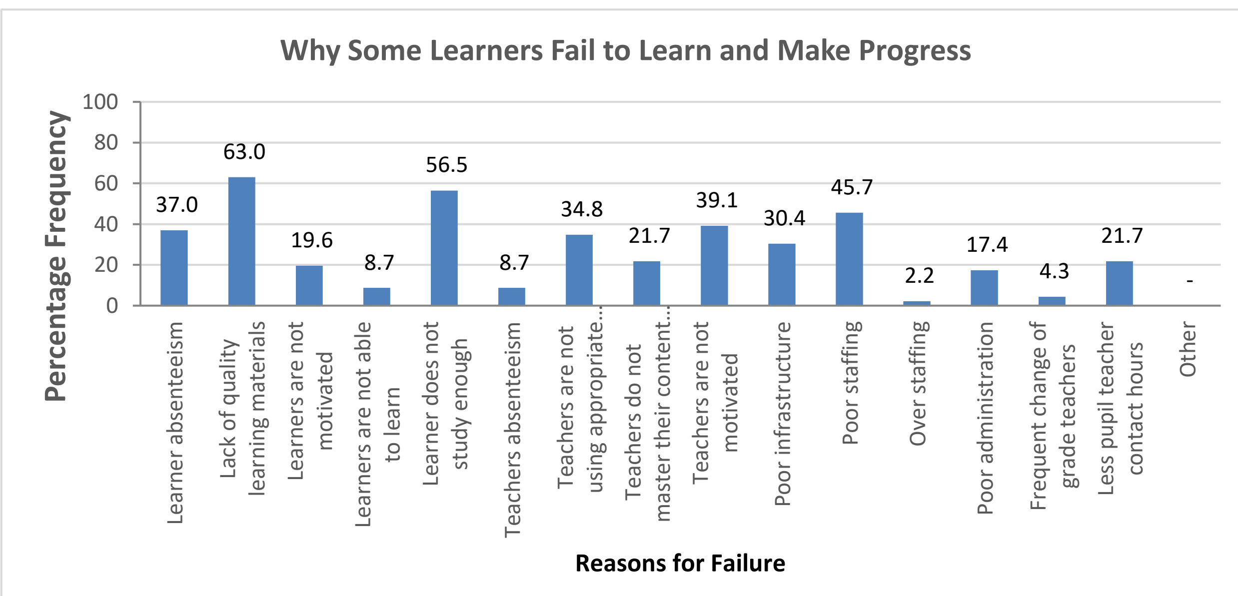


Figure 26: Why some learners fail to learn

However, in STEM education, HoDs need to develop strategies for ensuring that teachers assess performance against outcomes and provide real-time assessment results to the headteacher through the deputy headteacher.

4.1.3. Findings and Discussions on the Teacher Status of the STEM Schools

Teachers are a critical factor in the delivery of the intended Curricula to the learners. Therefore, it is cardinal that aspects of the teacher are analysed to determine their contribution towards the attainment of education. In this monitoring exercise, 266 teachers took part. Among these, 73 percent were male teachers while the rest (27%) were female. Figure 27 shows the distribution of the participants by Department.

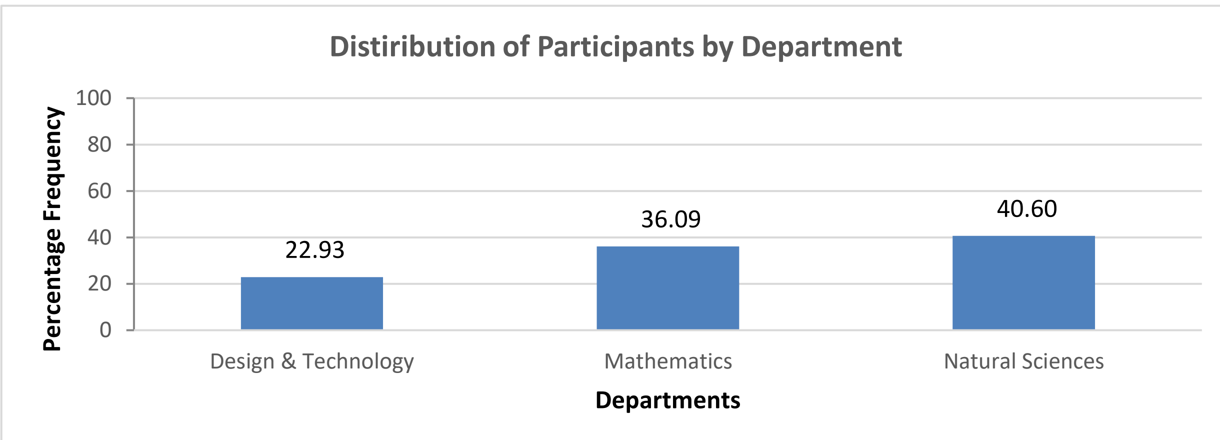


Figure 27: Distribution of Participants by Department

In Zambia, the imbalance in numbers of male and female teachers in the fields of STEM cannot be ignored. The 73 to 27 ratios of male to female teachers may have an effect on young female learners to work hard in their studies as they might not have readily available role models. This scenario may also perpetuate the stereotype of male domination in STEM Education. From the distribution of teachers by Department, it is apparent that the Design and Technology Department needs more teachers to deal with the increased number of learners who have opted to take the Technological STEM Education Curriculum.

More than 70 percent of the teachers had been serving as teachers in various schools for less than 15 years. Out of these, 53 percent had been serving at the current institutions for less than five years. The distribution of the subjects in which the teachers were trained is indicated in Figure 28. Five percent of the teachers had Masters Degrees, sixty two percent had Bachelor’s Degrees and 30 percent had Diploma as their highest qualifications.

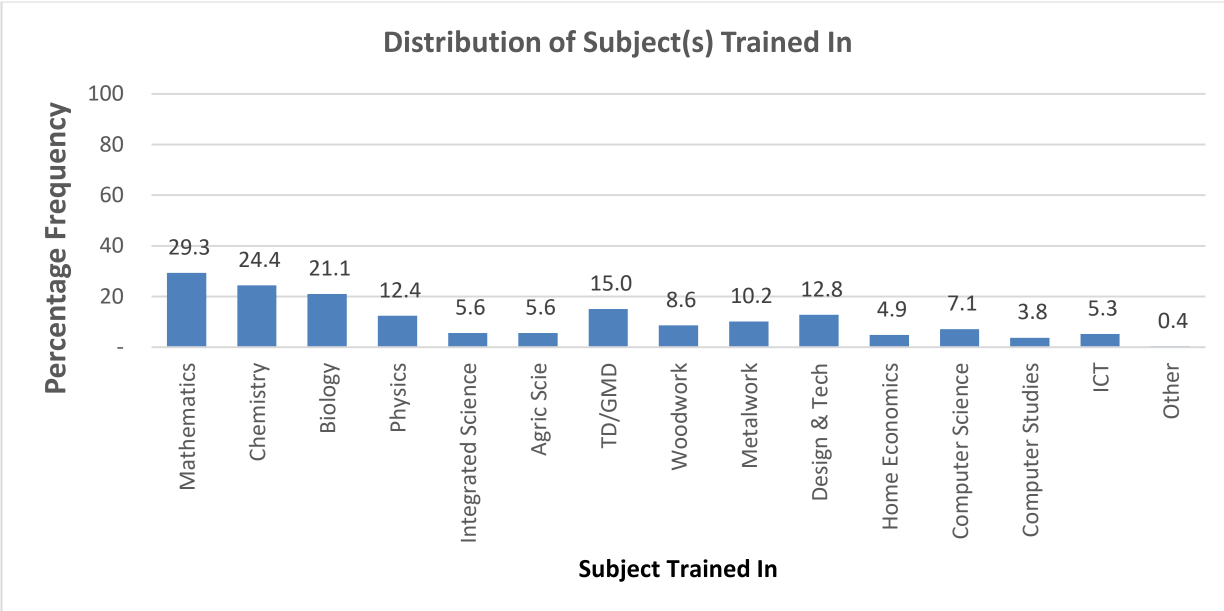


Figure 28: Distribution of Subject(s) Trained In

Figure 29 shows the percentage number of teachers teaching the various STEM subjects.

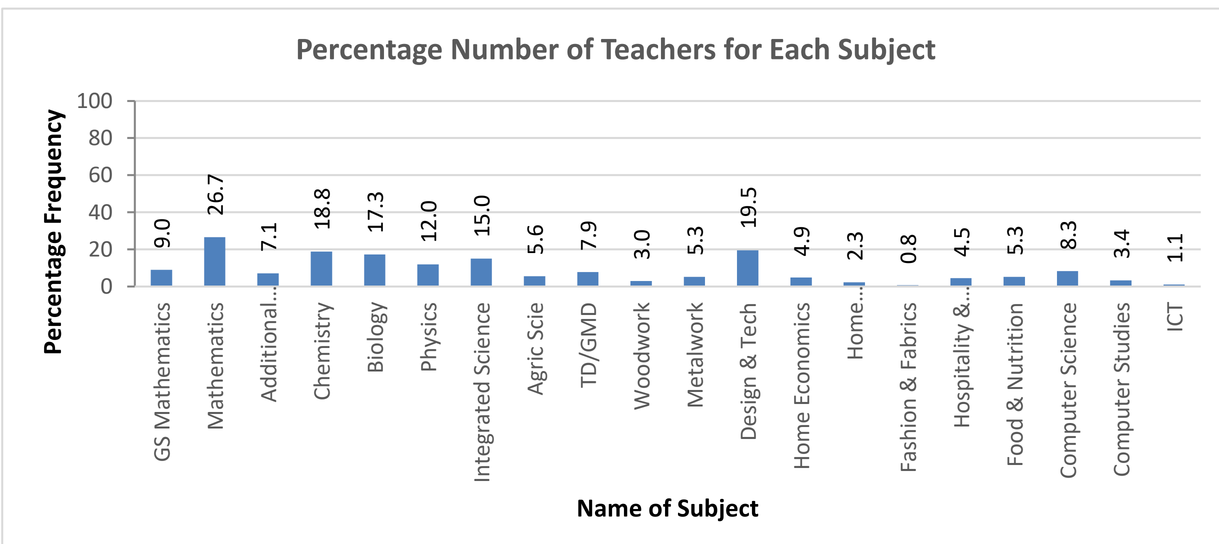


Figure 29: Percentage Number of Teachers for Each Subject

The fact that more than 70 percent of the teachers had been serving as teachers in various schools for less than 15 years shows a youthful cadre of staff who are trainable and can transform the way of teaching and learning in the Zambian schools. However, the insufficiency of teachers in some subjects such as Computer Science, Home Economics and Agricultural Sciences poses a threat in the actualisation of STEM Education. Therefore, there is need to consider training or recruiting more members of staff in these fields.

Among the professional competencies that teachers required to enhance their delivery of the STEM Curricula were pedagogical skills (49%), assessment skills (41%) and acquisition of more subject knowledge (36%). STEM Education requires teachers with research and enquiry skills for them to plan adequately and to design appropriate tasks for their learners. Therefore, teachers need to engage in CPD activities to upgrade their skills. The teachers' request to acquire professional competencies in pedagogical skills, assessment skills and subject knowledge is in agreement with the suggestions by their Head teachers and HoDs. Acquisition of such skills may be achieved in many ways including SBCPD activities using Lesson Study.

It was observed that the majority of teachers (53%) taught more than 24 periods per week. Teaching loads have an effect on the ability to offer quality lessons especially in the STEM dispensation as teachers are required to widely research and adequately prepare for their lessons. This requires sufficient time on the part of the teacher to plan and also have time for CPD activities. Therefore, high teaching loads by most of the teachers may affect the SBCPD as it would be challenging to find suitable time for such activities.

Almost all teachers (97%) confirmed that they had received the STEM Syllabi and other guiding documents. They also indicated that they downloaded and printed the documents and, thereafter, proceeded to hold Departmental meetings to discuss strategies for effective implementation of the STEM Curricula. Commencement of STEM teaching by most teachers was after receipt of the STEM Syllabi. However, some teachers started teaching as early as immediately after the grace period provided for late reporting learners (see Figure 30).

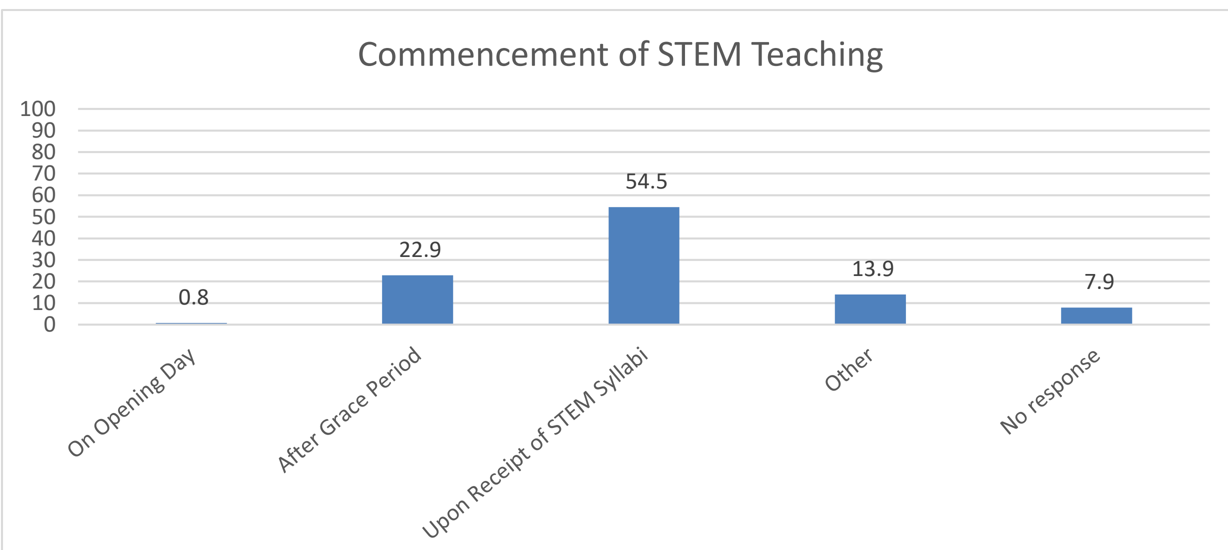


Figure 30: Commencement of STEM Teaching

The teachers who commenced teaching STEM Education prior to receipt of the STEM syllabi and guidelines might have started engaging the STEM learners using inappropriate teaching methods as they did not have the necessary documents. These teachers might also have found it difficult to shift from the positivist ways of lesson delivery to the constructivist processes.

Teachers reported that the learners' responses to STEM Education were positive and that their (learners) feelings about the teaching approaches employed by the teachers were affirmative as shown in Figure 31. It is apparent that learners have welcomed and accepted the STEM education along with their teaching approaches, going by the positive response and attitude toward the form of education by almost all learners in STEM schools. However, they need a lot of support from their teachers to guide them in the learning process.

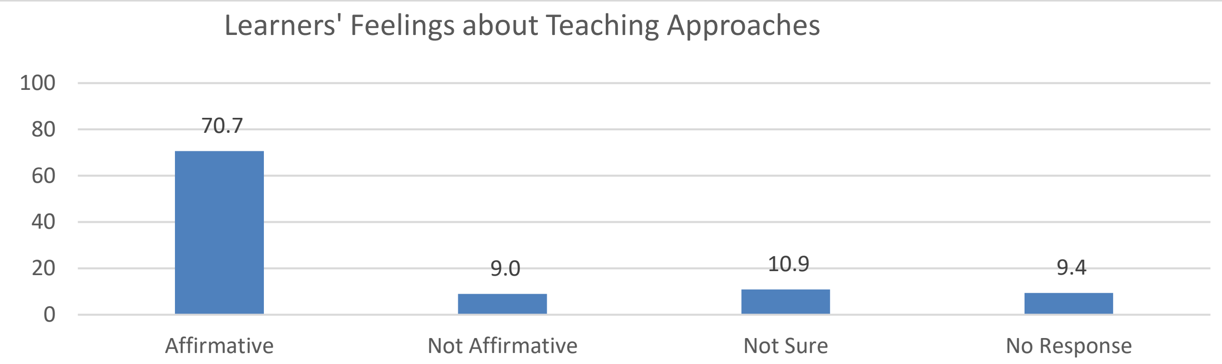


Figure 31: Learners' Feelings about Teaching Approaches

Therefore, teachers need to act as a learning facilitator, not a presenter of information. They need to employ various modes of learning including project-based learning which involves completing complex tasks that typically result in a realistic product, event, or presentation to an audience. They should not tell the learners what they (learners) need to discover but allow them to think for themselves, as discovery is a part of learning. Furthermore, teachers should convince learners to accept failure as normal and a necessary part of the process of learning. Thirty seven percent of teachers reported that their learners were using workbooks, 49 percent reported otherwise while 14 percent did not respond. Furthermore, 71 percent of the teachers did not indicate how often the learners were using these books. The issue of workbooks appeared to be a new phenomenon in STEM Education as revealed by the low number of teachers who reported learners using them. However, the workbook acts as evidence of learning and coverage of curriculum. In STEM Education learners are encouraged to record the experiences that they encounter during the learning process. Activities such as tasks and their solutions, experiments and research work can be documented in the workbook.

The types of ICT equipment used by most teachers are laptops (62%), printers (41%) and desktops (36%) as shown in Figure 32. Teachers stated that these and other teaching and learning materials were not sufficient and, therefore, implored for provision of more TLMs. Materials such as laboratory apparatus and models, heat sources, computers, electronic libraries, textbooks and projectors were among those teachers requested to be provided.

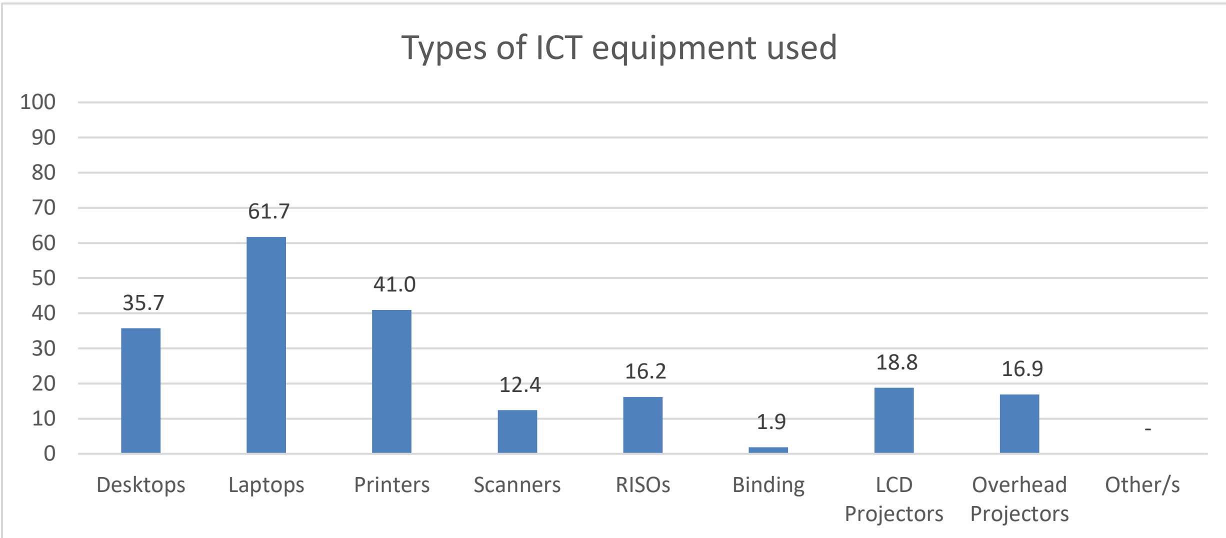


Figure 32: Types of ICT equipment used

STEM Education requires integration of technology in the learning process. Therefore, teachers need to be exposed to various types of ICT equipment for them to research widely and prepare adequately the tasks for the learners to work on. Learners alike need the ICT equipment for their research, monitoring of experiments, and for presentation of their findings and solutions. The authorities at various levels should consider addressing the insufficient quantities of the equipment in most schools so that teachers and learners access the equipment with ease. There is also need to consider supplying reliable internet connectivity in order to enhance research. Schools should restock Departments and libraries with adequate and useful TLMs and apparatus. The materials should include personal protective equipment (PPE) for both teachers and learners. With internet supplied, the e-library could be a workable solution for many textbooks, which teachers and learners could use.

Teachers attributed learners' failure to learn and make progress to lack of quality learning materials, the fact that learners did not study enough and because of their (learners) absenteeism from school (see Figure 33).

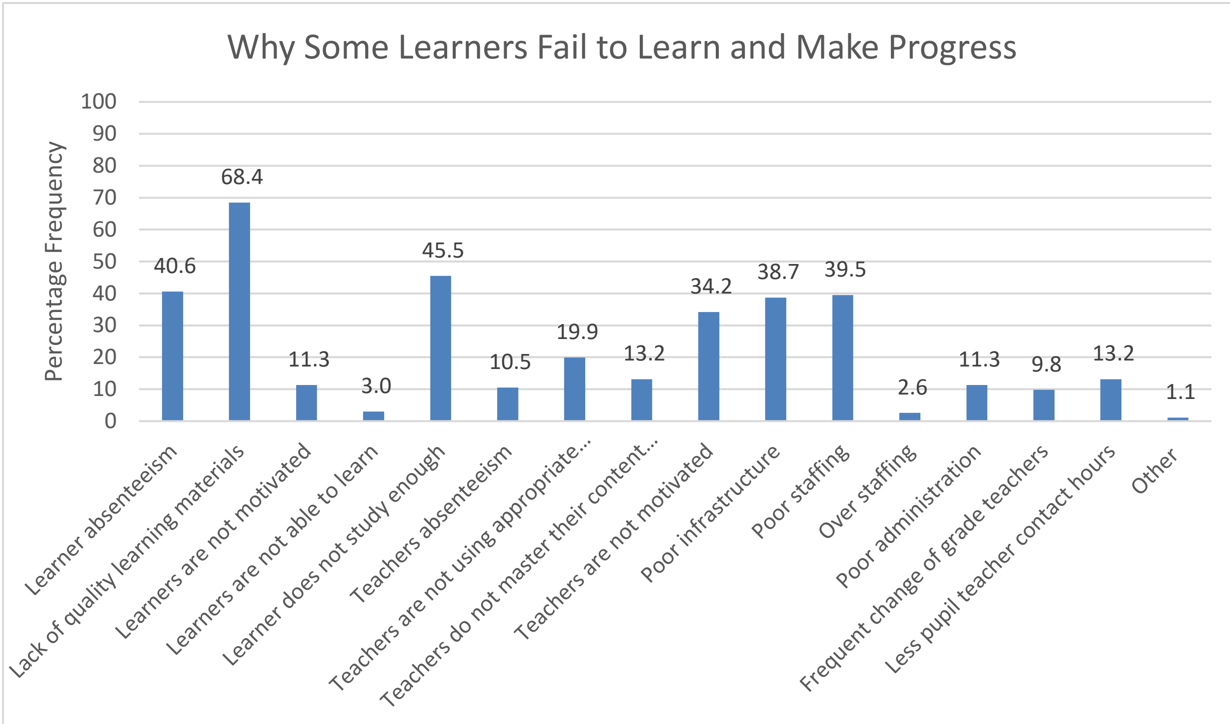


Figure 33: Why Some Learners Fail to Learn and Make Progress

Teachers should own up the failures of their learners. They need to discern and find out what causes low learner achievement. In most circumstances, teaching approaches and assessment skills play a big role in the learners' ability to learn and make progress in the learning process. Education today must focus on helping learners to learn how to learn, so that they can manage the demands of dynamic information, technologies, jobs, and social conditions. Therefore, putting the blame squarely on learners for their learning shortcomings will not change things.

Figure 34 shows the distribution of teachers' responses on the types of assessment they planned and administered to the learners. It was observed that most of the teachers had planned to administer tests, practical work and research work activities to their learners.

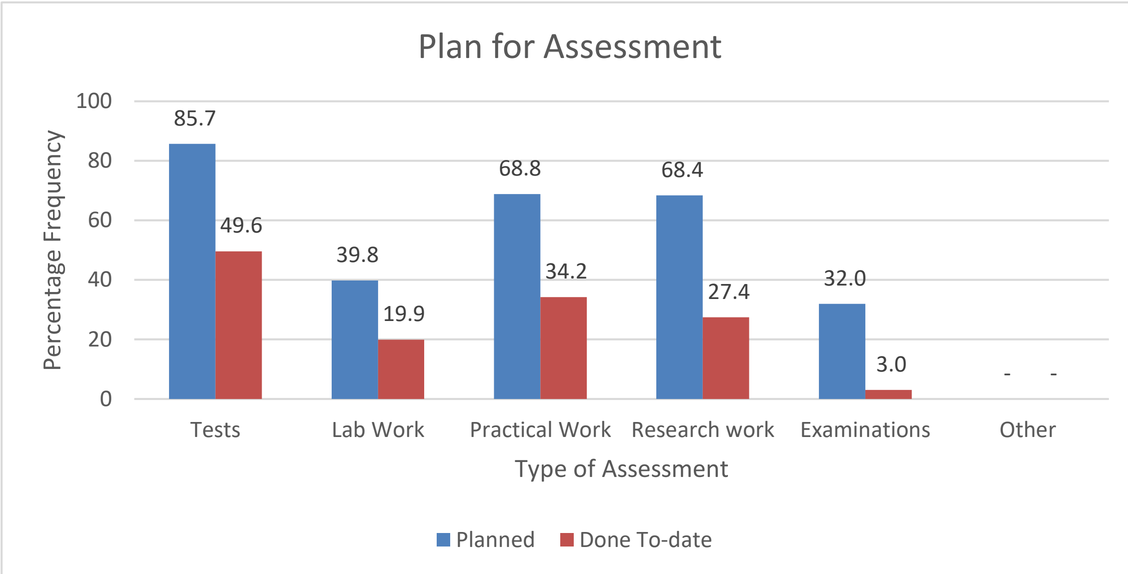


Figure 34: Plan for Assessment

From the results on planning for assessment, it can be inferred that teachers need a lot of capacity building in assessment skills. This is so because it is apparent that teachers did not seem to understand the guidance provided in the Guidelines and reverted to the 2013 curriculum way of assessing learning (administration of tests, exercises and examinations). Delay or failure to address this challenge may result in learners being ill assessed and may also result in demotivation of learners. In addition, if the assessments do not match with the curriculum and the outcomes, then results have little value in judging how well learners are learning and in diagnosing school or learner needs. On the contrary, STEM learners are expected to do more teacher-based assessments where continuous assessment, designed and marked by the learners' own teachers are conducted internally in the learning environment and counts towards a final grade of the learner. Hence, teachers ought to use appropriate methodologies for enhancing learning.

STEM Education - Curriculum Intentions and Implementation

STEM Education Curriculum intentions and implementation depends on the ability of teachers to interpret and execute curricula intentions correctly.

> *As Whitaker (1979) asserts, teachers view their role in curriculum implementation as an autonomous one. They select and decide what to teach from the prescribed curriculum. Since implementation takes place through the interaction of the learner and the planned learning opportunities, the role and influence of the teacher in the process is indisputable. Therefore, it is imperative that teachers translate and put into practice curriculum prescribed intentions correctly in order to help learners acquire the necessary knowledge, skills and competencies.*

The intentions of the transitional STEM curricula needed to be implemented correctly and therefore, the findings on curriculum intentions included aspects of planning for lessons, resource materials consulted and the preparation of teaching and learning aids. It is well recognized that Curriculum intentions and implementations could be analysed from several perspectives. However, in this research, the STEM Education Curriculum intentions and implementation were analysed and discussed from three angles namely: Planning for Lessons, Planning for Resource Materials and Planning for Teaching & Learning Aids Preparation.

4.1.4. Planning for Lessons

As earlier alluded to in Chapter 3, planning for lessons involves a lot of activities which may include determining how the teacher, learners and curriculum interact, amongst others. In this context the findings and discussions on planning for lessons focused on:

a) Planning for Lesson in Relation to Curriculum Intentions,
b) Planning for Lesson in Relation to Curriculum Implementation.

Planning for lesson in relation to Curriculum Intentions pays attention on the teacher's understanding of the curriculum and its intentions on a particular topic. It also goes beyond to understand what other relevant documents the teacher referred to before writing the lesson plan. In relation to Curriculum Implementation, planning for lesson relates to understanding the teacher's plan of lesson delivery. This mainly involves the teacher's plan of the flow of the lesson including rationale formulation, planning for lesson introduction, development and conclusion. These aspects were analysed with reference to trends within and across subjects and grades. The subjects analysed were: Agricultural Science, Biology, Chemistry, Computer Science, Design & Technology, Hospitality & Tourism, Mathematics and Physics.

4.1.4.1. Planning for Lesson in Relation to Curriculum Intentions

The findings and discussions on lesson planning aspects were based on how the topic, sub-topic, outcomes and knowledge were in conformity with curriculum intentions**.** The findings and analysis of planning for lesson aspects in relation to the curriculum, in Agricultural Science, Biology, Chemistry, Computer Science, Design & Technology, Hospitality & Tourism, Mathematics and Physics are shown below:

a) Agricultural Science

In the case of Agricultural Science, the total number of lessons interacted with in this survey was four, of which one was junior (Grade 8) and the other three were senior (Grade 10) lessons. The findings shown in Figure 35 indicated that at junior, the lesson topic and sub-topic were completely not in line with curriculum intentions. Furthermore, at senior level 67% of sub-topics, outcomes and were not in conformity with curriculum intent. Conversely, 67% of lesson topics at senior level were in line with the curriculum intentions as indicated in the syllabus.

Teachers failed to excerpt the topic and sub-topic from the curriculum at junior level meanwhile they were able to use the correct outcomes and knowledge as specified in the STEM Transitional syllabus. For instance, the topic found on the junior lesson plan was *farm tools* and the sub-topic

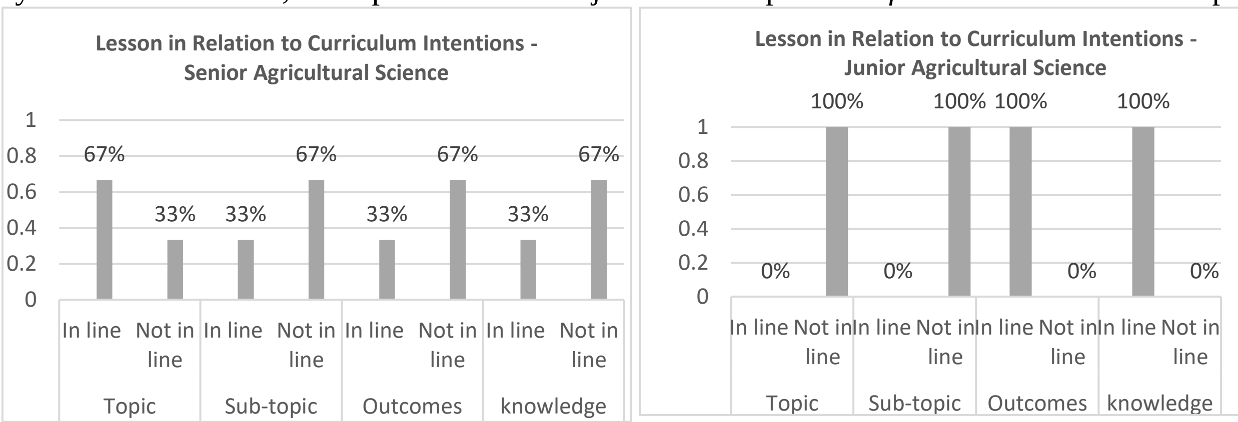


Figure 35: Planning for Lessons in Relation to Curriculum Intentions in Agricultural Science at both Junior and Senior Levels

as *Agricultural Sprayer*. However, the topic was not one of those indicated in the STEM Transitional syllabus. At senior level the teachers had an average understanding of the lesson topic, which was in line with the STEM Transitional syllabus, but not the sub-topic, lesson outcomes and knowledge. The findings from the planning for lessons show that there were disparities in the level of knowledge of the curriculum amongst teachers of Agricultural Science as seen from the variations at junior and senior levels as regards to lesson aspects in relation to curriculum intent.

This could have been as a result of teachers not having intensive study of the curriculum so as to familiarize themselves with particular curricula intent. Additionally, it also could have been due to over-dependence on textbooks where teachers unconsciously tended to pick sub-topics as indicated in such reference materials. Further, teachers might have had an inclination of falling back on the dictates of the 2013 syllabus as opposed to focusing on the STEM Transitional syllabus. It is important that the Agricultural Science curriculum intent is understood and interpreted correctly. This is so because Agricultural Science in Zambia is part of STEM education with a focus on developing learners who will form a knowledgeable modern-day workforce with skills applicable in the development of sustainable agro practices, products and services needed to address social, economic and environmental challenges. Teachers being the main curriculum implementation drivers, their professional development are critical as it would help them extensively study and understand the curriculum intentions. Therefore, their capacitation is essential.

b) Biology

As regards to Biology, the total number of lessons investigated was five of which two were for junior (Grade 8) and 3 senior (Grade 10). The findings as shown in Figure 36 at Grade 10 level, indicate that lesson topics, sub-topics, outcome and knowledge were all only at 33% in conformity with curriculum intentions whilst the junior level showed 100% conformity for the lesson sub-topic, outcomes and knowledge with average conformity of the topics at 50%.

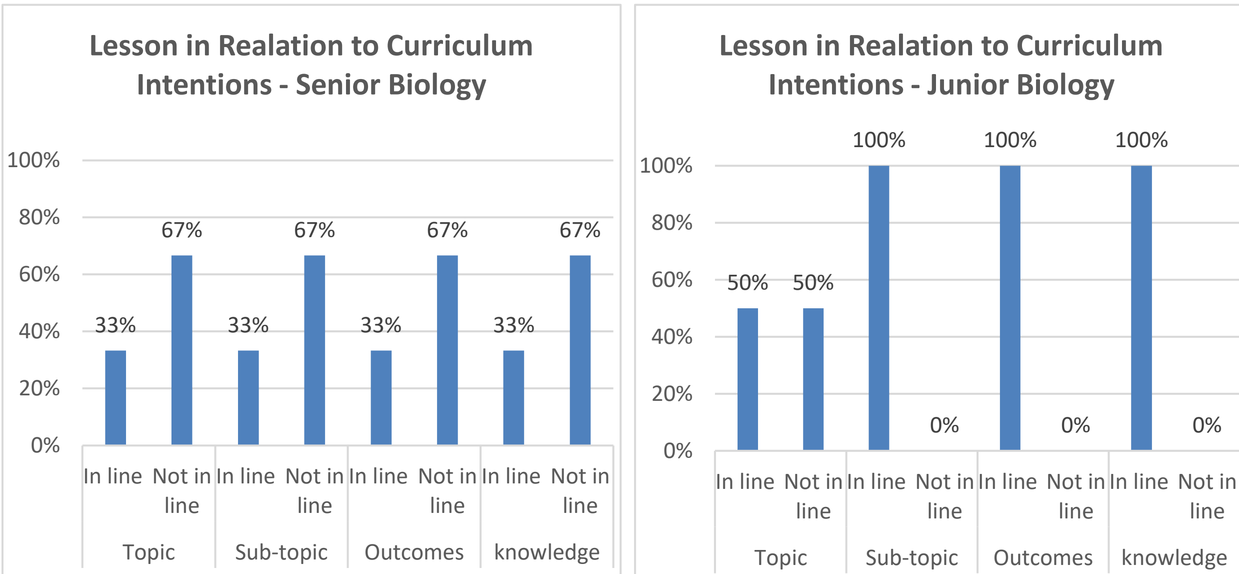


Figure 36: Planning for Lessons in Biology in Relation to Curriculum Intentions at both Junior and Senior Levels

Generally, the teachers of Biology appeared to have conducted intensive study of the curriculum as they planned for lessons which led to their understanding of the curriculum intent. The implication is that when the curriculum intent is correctly planned for, it would facilitate the gain of Biology knowledge necessary for 21st Century learners. The importance of Biology in STEM education goes beyond taking specimen of plants and animals to the laboratory and looking at them to describe what is seen. Rather it must apply knowledge to solve problems of contemporary times such as environmental crisis of climate change, biodiversity loss, introduction of non-native species, emerging & pandemic diseases and improvement of food supply. To this effect the correct interpretation of Biology STEM Education Curriculum intent cannot be overemphasized. For the senior level the results showed that there was less indication of lesson aspects (topic, sub-topic, outcomes and knowledge) in line with curriculum intent. This could have been due to teachers' lack of knowledge of the curriculum to interpret its demands. Another reason could be inadequate time dedicated by teachers to plan for lessons hence relying on their already known knowledge that could have been at variance with dictates of Biology STEM transitional curriculum. To remedy this therefore, a reorientation of STEM Biology teachers on curriculum understanding and strengthened Biology teacher group continuing professional development activities in schools should be vibrant.

c) Chemistry

The total number of Chemistry lessons in this research was 5 with 1 junior (Grade 8) and 4 senior (Grade 10). The results in Figure 31 showed that all the Chemistry lesson intentions at junior level was in accordance with curriculum intentions with the topic, sub-topics and outcome translating into 100% compliance. However, the knowledge was completely not in line with curricula intent. As regards to the senior Chemistry lessons 3 out of out of 4 translating into 75% of the topics, 50% of sub-topics, 25% of the outcomes and 50% of the knowledge were in line with curriculum intentions as shown in Figure 37.

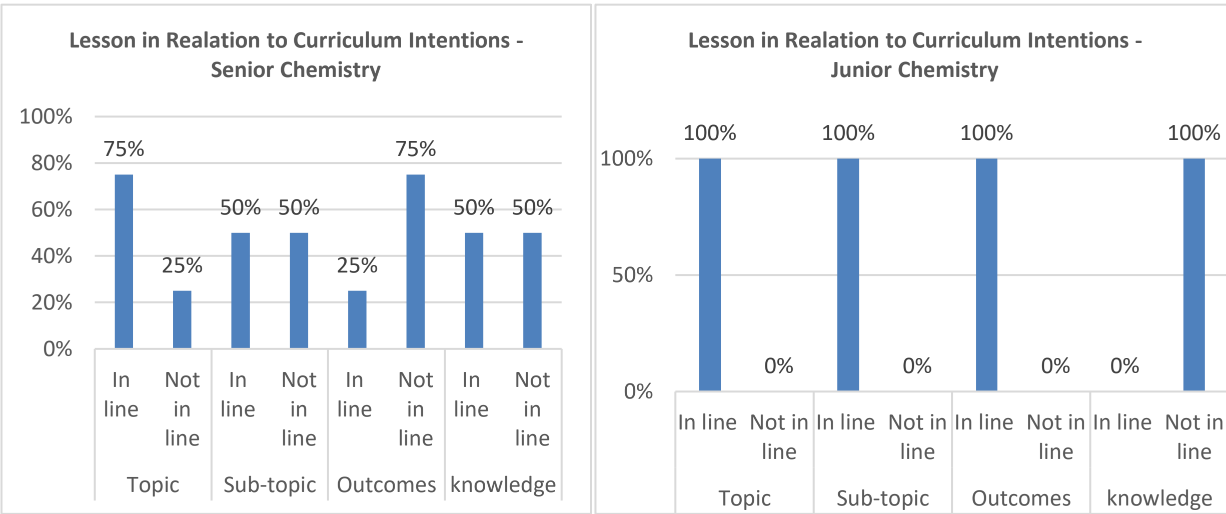


Figure 37: Planning for Lessons in Chemistry in Relation to Curriculum Intentions at both Junior and Senior Levels

From the findings above on senior Chemistry lessons, planning for sub-topic, outcomes and knowledge showed that teachers did not extract correct curriculum intent. This could be as a result of teachers not understanding the curriculum or not extracting useful information needed to interpret STEM Education Curriculum intentions from various resource materials they referred to. Additionally, the discrepancy in the results between senior and junior levels signifies variance in curriculum understanding. The reason why the senior Chemistry planning had most aspects not being in line with the curriculum was that there could have been a tendency of some teachers consulting the 2013 syllabus instead of the 2019 STEM Transitional curriculum. One case in point amongst others is that of a lesson with topic "measurement *of quantities*" sub-topic "*laboratory apparatus in the measurement of physical quantities*" and specific outcomes as "demonstrate *the appreciation of the use of standard units of measurement of physical quantities* and *demonstrate the mathematical manipulation of the conversion of physical quantities"*. All these aspects are not in the Chemistry senior STEM transitional curriculum. The implication of this would be that learners will be given information not meant for them. This would inhibit not only the acquisition of appropriate knowledge but also the development of desired skills needed in understanding and improving chemical science for the betterment of contemporary society. For this reason, there is need to strengthen communities of practice amongst the teachers of Chemistry so that they could have a common knowledge of curriculum understanding. Communities of practice are important in that they enable information sharing through discussions, encourage use of knowledge to promote and sustain learning, Wenger (1998).

d) Computer Science

Out of the seven lessons monitored in Computer Science, the findings were that all the five (5) senior lessons and one (1) junior lesson had topics not in line with the intentions of the Curriculum as shown in figure 32. Additionally, 80% of the senior lesson's sub-topics and 50% of junior were not related to the dictates of the Curriculum. Furthermore, 20% and 80% of the outcomes for junior and senior lessons were not in line with what the Curriculum demands respectively. Knowledge for both senior and junior lessons was equally unimpressive as 100% and 80% for junior and senior lessons were off the mark in relation to the intentions of the Curriculum respectively.

The findings revealed some concerns which seem to arise from failure by some teachers of

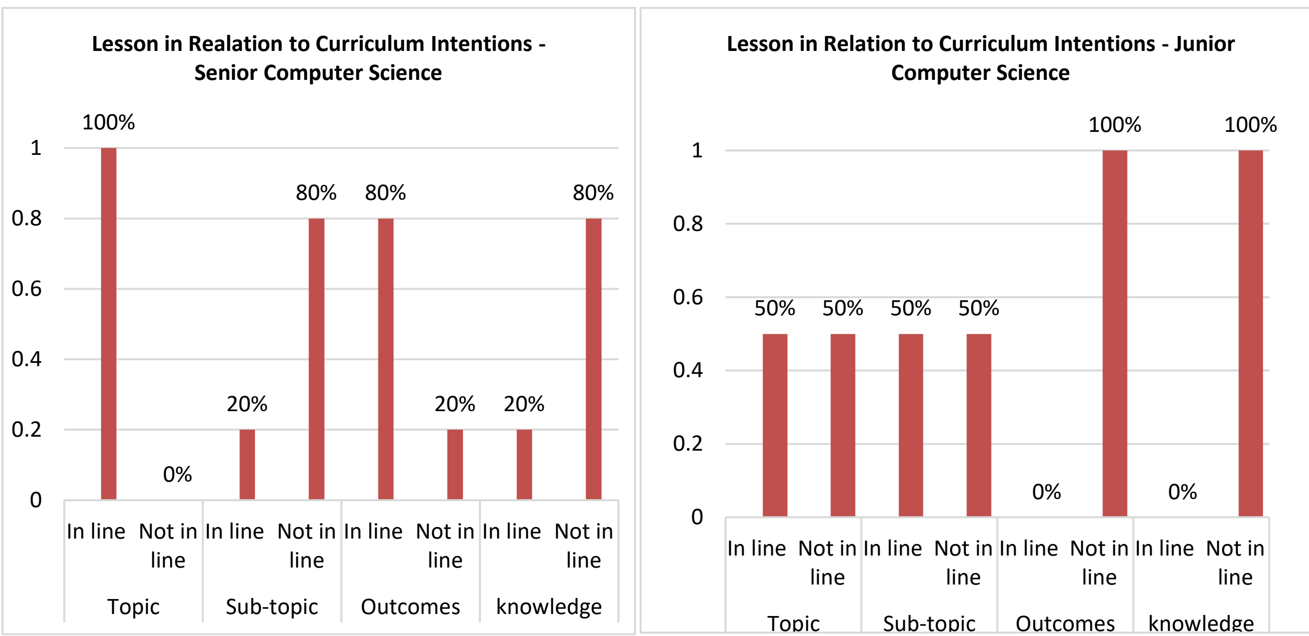


Figure 38: Planning for Lessons in Computer Science in Relation to Curriculum Intentions at both Junior and Senior Levels

Computer Science to first read thoroughly the intentions of the Curriculum before embarking on facilitation in their respective classes at either grade eight (8) or grade ten (10). Looking at grade eight (8) where one lesson had a topic not in line with the dictates of the Curriculum one wonders where the teacher got the write up from to put in the plan and later execute it. The STEM teacher has the responsibility of interacting with the Transitional Curriculum in order to not only understand its structure but the flow and meaning of the contents. This would put the teacher in a better position to interpret the Curriculum accurately for effecting guidance during teaching and learning at all the time of facilitation. On one hand, it could have been that the teacher did not consult the 2019 Computer Science Curriculum resulting in the mismatch between what is contained in the lesson plan and the actual topic outlined in the document which was made available to all the stakeholders. On the other hand, the teacher might have checked the Curriculum which was not meant for the current grade eight negating the transformation which the Ministry had approved for the learners from the year 2020. Additionally, the teacher might have relied heavily on the text books available either at personal or institutional level leading to misrepresentation of content away from the actual as demanded by the Transitional Curriculum. Conversely, 100% topic representation in grade ten implies that the teachers had taken time to interact with the Curriculum and its contents hence picking what was expected of them in terms of the topics at that level. However, this becomes of concern to see that the same teachers could not synchronize the topics to their sub-topics which were situated right next to each other in the Curriculum. It therefore meant that much as the teachers picked the actual topics, they might not have gone further to study the other related areas within the Curriculum. One would therefore argue that, the study of the Curriculum with the view to understand it fully was not taken with the seriousness that it deserved rather that teachers may have just glanced at it and quickly started framing their own things which the guide does not agree with in the framework. The implication of such piecemeal treatment of the Curriculum would be that its intentions to produce a learner who is critical, creative, analytical, problem-solver and responsible citizen may not be easy to attain as the facilitators were using disjointed approach as opposed to what had been provided.

The outcomes are stated in the Curriculum for reference when planning for lessons. They are carefully put there in direct relation to the topic and sub-topics in order to create coherence both in content and context. Therefore, having 100% mismatch at grade eight (8) level and 20% not being in line at grade ten (10) level can only mean that some teachers are not able to read the Curriculum for understanding. Teachers are spending minimal time to read through the Curriculum in order to guide the learners as is excepted resulting in mix-ups as they plan for lessons. The findings reveal grey areas in the competences of the teachers as far as skills of using reference materials are concerned. Although teachers may be in possession of the Curriculum as a fundamental reference material before planning for their lessons, its effective use is highly questionable as they fail to copy from it when required to do so. Ultimately, the knowledge that they shared with the learners, as indicated in Figure 38 tended to be out of tune with the expectations of the Curriculum. The implications are that learners are fed with the intentions of the teachers and not those of the curriculum and this situation may be detrimental to the education system as a whole. To mitigate the situation before it spirals out of manageable sphere, Curriculum training sessions need to be drafted in which teachers will be taken through the critical steps on how to extract vital information from the official documents to promote effective lesson delivery within the confines of the Curriculum.

e) Design and Technology

In Design and Technology out of the 9 lessons under study, six (6) were junior (Grade 8) lessons and two (2) were senior (Grade 10) Graphic Communication while one (1) was senior Systems Technology. For the senior level lesson plan, 33% of the lesson's topics, sub-topics and outcomes were not in accordance whilst the knowledge was 67% in accordance with dictates of the Design

& Technology STEM Transitional Curriculum. Similarly, for the junior lesson plans 67% of lesson topics, 33 % of lesson sub-topics, 17% of lesson outcomes and 33% of lesson content knowledge were in accordance with curriculum dictates as shown in Figure 39.

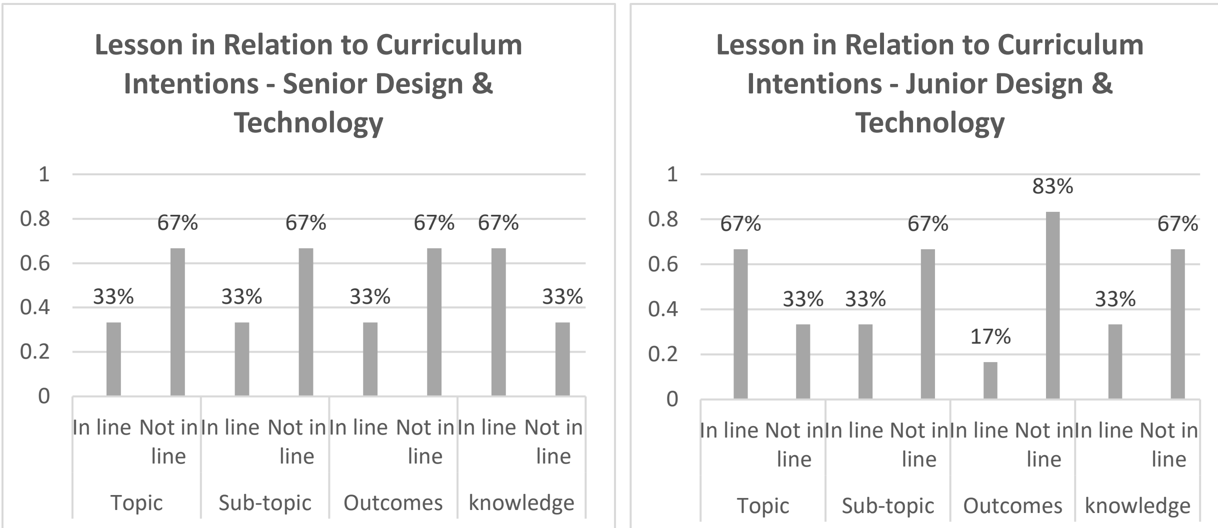


Figure 39: Planning for Lessons in Design and Technology in Relation to Curriculum Intentions at both Junior and Senior Levels

The findings show that there was a gap in terms of curriculum understanding at junior and senior levels. At senior level teachers were able to extract the topic and knowledge very well from the curriculum and not the sub-topics and outcomes meanwhile at junior level teachers where able to extract well the topic and not the sub-topics, outcomes and knowledge. Cases in point, amongst others, include one in Systems Technology lesson at junior which had the lesson outcome as "*Manipulate materials to realize a product that will be used to solve a given problem*". In the syllabus this is a value and not an outcome. Another case was that of a lesson where the outcome was "*Draw symbols of identified electronic components*" in the syllabus this was supposed to be part of the knowledge on the outcome "*Identification of basic electronic components"*. The reason for this non conformity to curriculum intentions could be lack of teachers intensively interacting with the curriculum and hence having limited understanding of it. In the case of the knowledge content not being in line with the curriculum intent it could have been influenced by the teaching and learning resources consulted. The implication of this is that wrong content might have been given to learners ultimately which could negatively affect the implemented and attained curriculum. To mitigate this, schools should be encouraged to strengthen collaborative practices through SBCPD activities such as capacitation training of teachers in curriculum understanding and development of STEM teaching resources should be on going.

f) Hospitality & Tourism

In Hospitality & Tourism, out of the two (2) lessons in this study, one (1) was at junior (Grade 8) and the other one (1) at senior (Grade 10). For both junior and senior levels, the lessons' topic, sub-topic, outcome and knowledge aspects were all at 100% except for the sub-topic at junior level, signifying that these aspects were in accordance with curriculum intentions as indicated in Figure 40.

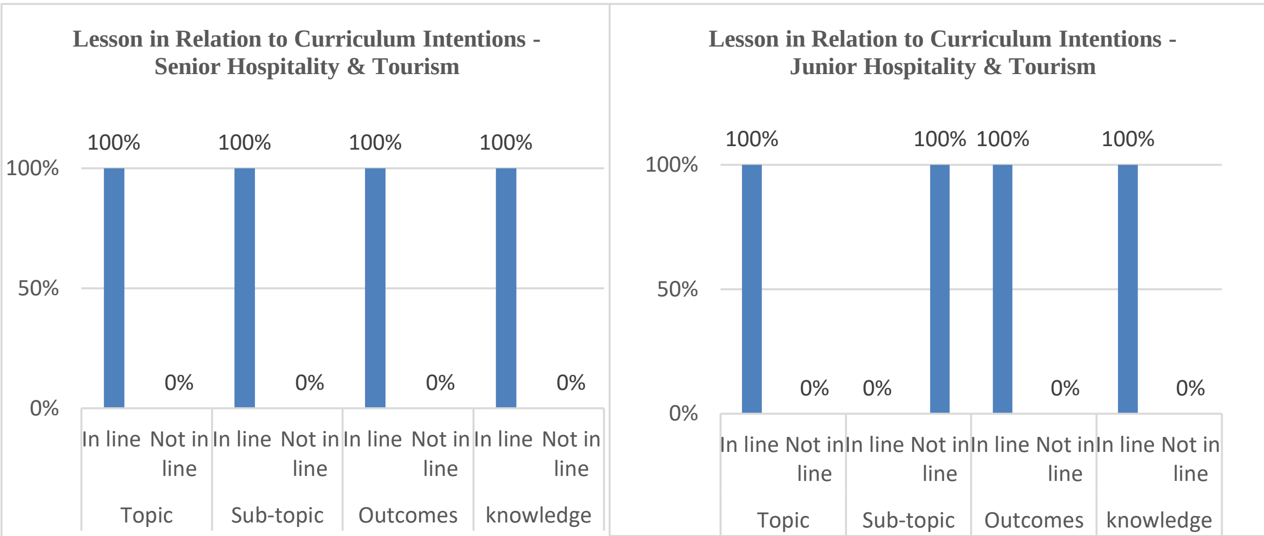


Figure 40: Lessons in Hospitality & Tourism in Relation to Curriculum Intentions at both Junior and Senior Levels

The conformity to curriculum intentions could be as a result of teachers' adequate intensive interaction with the curriculum and hence they developed minimum competencies and skills to interpret it correctly. The implication of this is that correct content was given to learners. Ultimately this would positively affect the implemented and attained curriculum. This means that the aim of Hospitality & Tourism learning area which is to develop intellectual capacities for life-long learning through promotion of interpersonal, communicative and problem-solving skills amongst others would easily be realized. To continue designing responsive instructional aspects in the implementation of the Hospitality & Tourism STEM Education Curriculum, a system of sustained collegiality should be encouraged.

g) Mathematics

The findings under Mathematics which had 11 lessons observed in total with 5 being senior (Grade 10) and 6 junior (Grade 8) showed, according to Figure 41, that at senior level the lesson topic, subtopic and outcomes in all the five lesson plans analysed were in conformity with curriculum dictates. However, in terms of knowledge three out of the five lessons translating into 60% were in line with curriculum dictates. The junior level lessons showed that all the six lessons translating into 100% had topics in line with curriculum dictates whilst 5 out of six, representing 83%, had subtopics indicated on lesson plan in line with curriculum intentions. Conversely, half of the lesson plans had outcomes and content not being in line with the curriculum.

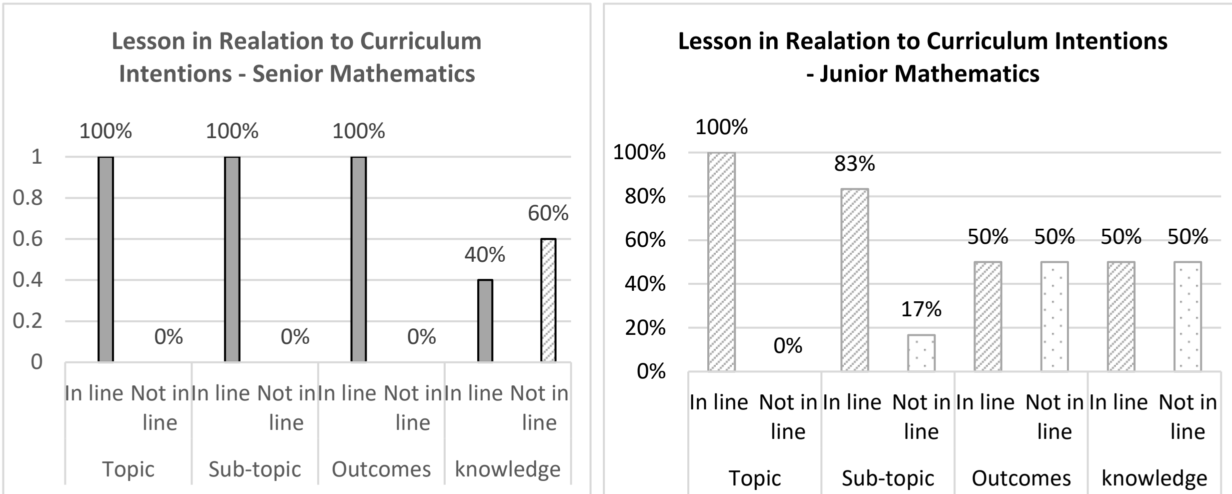


Figure 41: Planning for Lessons in Mathematics in Relation to Curriculum Intentions at both Junior and Senior Levels

The general impression of this is that teachers were ably consulting the curriculum. The implication of this is that learning aspects being learnt were appropriate as the lesson topics were in line with curriculum prescriptions. This ultimately helps learners to obtain mathematical proficiencies required in the global 21st Century economy through correct knowledge and skills interpreted by the teachers. However, the revelation that knowledge content at both grade levels had an approximate average of only half the lessons being in line with curriculum dictates becomes of great concern. The knowledge aspect in the curriculum helps specify and delimit the subject matter that should be learnt in a particular lesson. This situation, where the knowledge intent in planned lessons was not in line with the curriculum, could imply lack of curriculum understanding on the part of Mathematics teachers, as regards to what was to be taught and learnt. Additionally, it can also be attributed to the influence of teaching and learning resources consulted, as teachers could not make cross reference with what the curriculum intent was but relied heavily on learning resources. To remedy this, supportive STEM in-service teacher pedagogical content knowledge capacity building programs, that include tailor made training and individual teacher follow-ups, need to be put in place. This is so because curriculum policy reform will not have the desired effect if it is not accompanied by a vibrant capacity building program.

h) Physics

In the case of Physics five lessons were observed of which four were at junior level and one was a senior level lesson. On the one hand, the findings as shown in Figure 42 indicated that the senior Grade 10 Physics lesson was in line with corresponding STEM Education Curriculum intentions as the lesson topic, sub-topic, outcome and knowledge were at 100% conformity with stipulated curriculum prescriptions. On the other hand, the junior Grade 8 lessons showed that three out of the four lessons translating into 75% were in line with the curriculum intentions as the topics, sub-topics and knowledge were 50%, 25% and 50% respectively.

As regards to senior Physics, the outstanding conformity (topic, sub-topic, outcomes and knowledge) with curriculum intentions as indicated in the results in Figure 36 entails that the

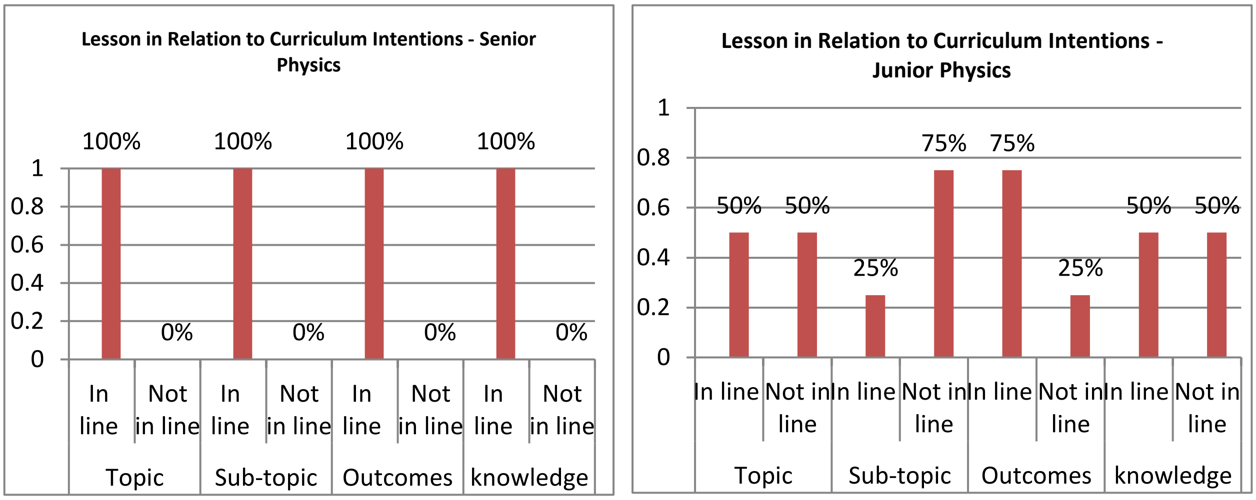


Figure 42: Planning for Lessons in Physics in Relation to Curriculum Intentions at both Junior and Senior Levels

teachers interacted effectively with the curriculum and hence were able to interpret it's dictates correctly as they planned for lessons. The implication of this is that the concepts, ideas and knowledge that the learners were expected to acquire and develop were all suitably planned for and so the lesson was expected to yield the desired outcomes. Conversely, as observed at junior level only 75% of lesson outcomes were in conformity with curriculum intentions whilst the topic, subtopic and knowledge were either average or below. This becomes of great concern because on one hand teachers obtained and translated correct curriculum intent whilst on the other hand they could not. This could be as a result of teachers not consulting the correct curriculum as they planned for their lessons. The 50% disparity on topics as a case in point was as a result of the 2 lessons stating the topics as "*Matter and Measurements*" instead of the correct topic indicated in the transitional Integrated Science 3 Curriculum which is "*Physical Quantities of Matter*". Another reason could be that teachers were using their personal discretion based on past experiences with the non-STEM Education Curriculum to devise the topics, subtopics and outcomes as they planned for lessons. Other than that, this could also have been as a result of teachers relying on what was stipulated in the teaching and learning resources without cross referencing with what the approved 2019 STEM Transitional syllabus prescribed. As regards to the disparity between senior and junior levels, there is clear indication that teachers were at different levels of understanding the intended STEM Education Curriculum. The implication of this would be that the lesson plans that conformed with the curriculum had the correct content and therefore had a better understanding of what learners needed to learn. The lesson plans whose intent was not in line implied that the content learners needed to learn was misguiding. Ultimately this could impede the development of desired learning outcomes for the 21st Century learners. This is so because Physics contributes to the increasingly technological advancements used in everyday life. It is imperative therefore, that the content that has been placed in the Physics STEM Education Curriculum be correctly transmitted to the learners as it was carefully selected to help prepare learners acquire the necessary knowledge and competencies needed to adapt in modern society. There is need to reorient teachers of Physics in STEM Education Curriculum interpretation and also for them to strengthen their collegiality activities aimed at sharing knowledge and deepening their understanding of curriculum intentions.

Summary of Lesson Aspects in Relation to Curriculum Intentions

Generally, across all the subjects the findings indicated that there was average understanding of lesson aspects in relation to curriculum intentions. Fifty-three percent of lesson subtopics and outcomes were not in line with curriculum intentions whilst only 47% of the content knowledge was in conformity with curriculum dictates. As regards to the lesson topics 69% were in accordance with curriculum prescriptions as shown in Figure 43.

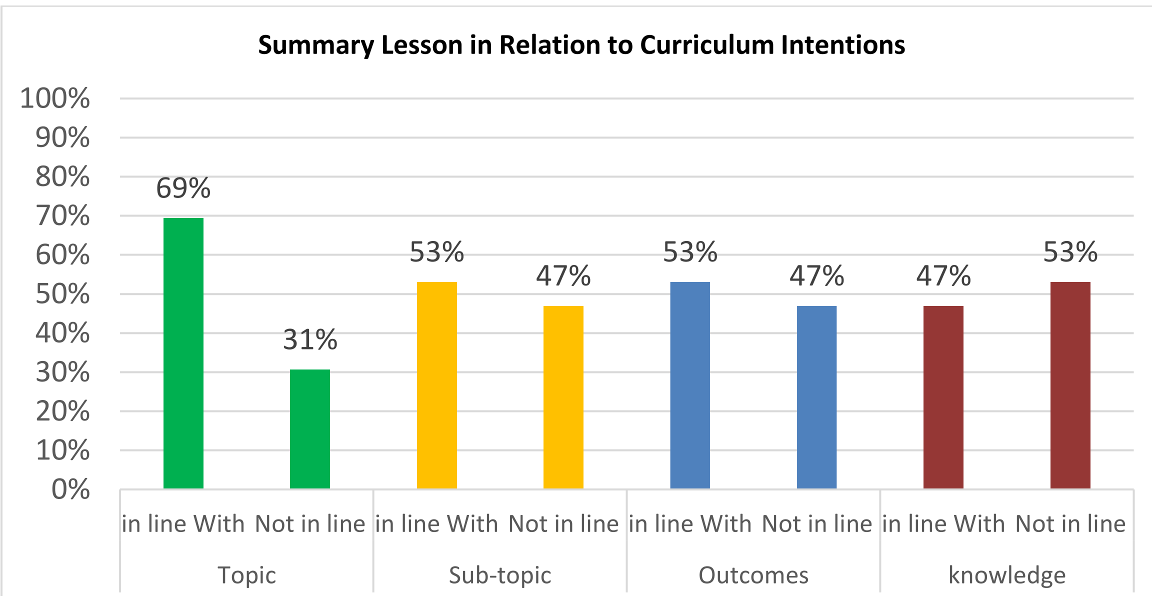


Figure 43: Summary Lesson in Relation to Curriculum Intentions

From the findings it was evident that there was inability to excerpt correct aspects (subtopics, outcomes and content knowledge) from the curriculum to use in planning for lessons. This could suggest that in some cases the 2013 syllabus influenced the content knowledge that was planned. Additionally, it could also insinuate that there could have been heavy reliance on text books and so the layout and topic headings of textbooks persuaded the choice of topics, subtopic, lesson outcomes and content knowledge. The implication of teachers not extracting curriculum aspects appropriately could be that lesson delivery would also be affected and ultimately this would impede attainment of curriculum intentions.

4.1.4.2. Planning for Lesson in Relation to Curriculum Implementation

i. ***Preliminaries to Planning for Lesson in Relation to Curriculum Implementation***

Lesson planning is a detailed description of the course of instruction. It is a step by step trajectory of what learners should learn and how it should be done. The outline details of lesson plans can vary however; it should carry certain aspects that detail stages of concept acquisition. In this context lesson planning focused on not only whether the lessons were collaboratively planned but also whether the lessons had plans to clear misconceptions as well as assessment criterion plans. Another aspect considered was whether the lessons were planned using an open or predetermined lesson template, further it looked at aspects of rationale formulation, planning for lesson introduction, development and conclusion. The finding and analyses across the subjects were as follows:

a) Agricultural Science

Four lessons were observed in Agricultural Science. Out of these 1 was at junior level and the other 3 were at senior level. The lesson planning findings revealed that at both senior and junior levels individual lesson planning was prevalent as opposed to collaborative planning as shown in Figure 44. Regarding misconceptions, this was not planned for in the junior lesson. However, 67% of senior lesson plans had planned how misconceptions were to be handled. The results also indicated that at all the senior lesson plans were written on predetermined lesson plan formats while, at junior level the lesson plan was written on an open lesson plan format. Both predetermined and open lesson plan formats have both merits and demerits. It was also observed that 33% of the senior lesson plans had assessment criterion plans while the junior lesson plan did not have.

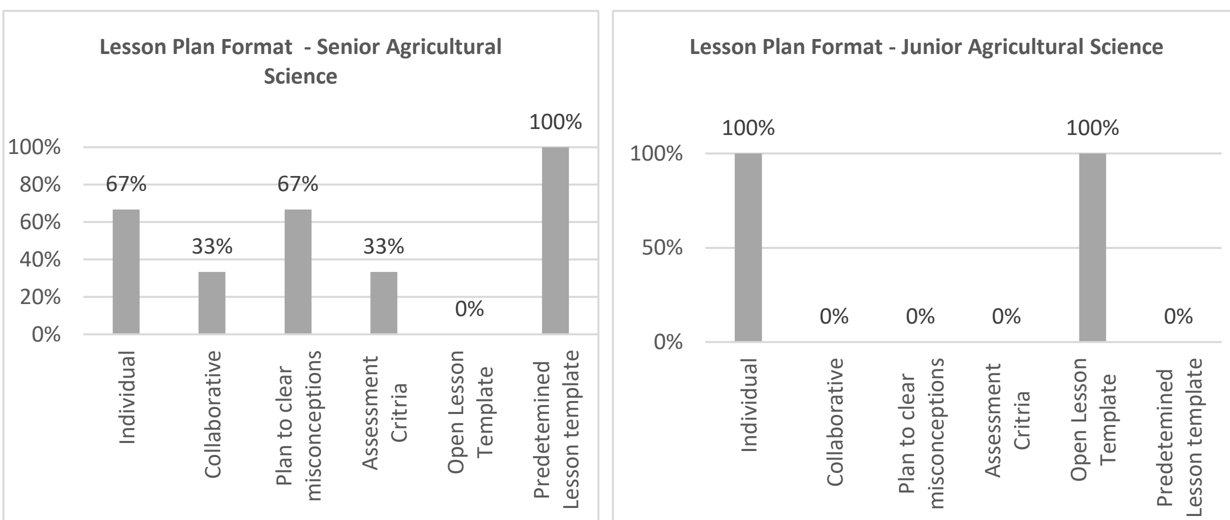
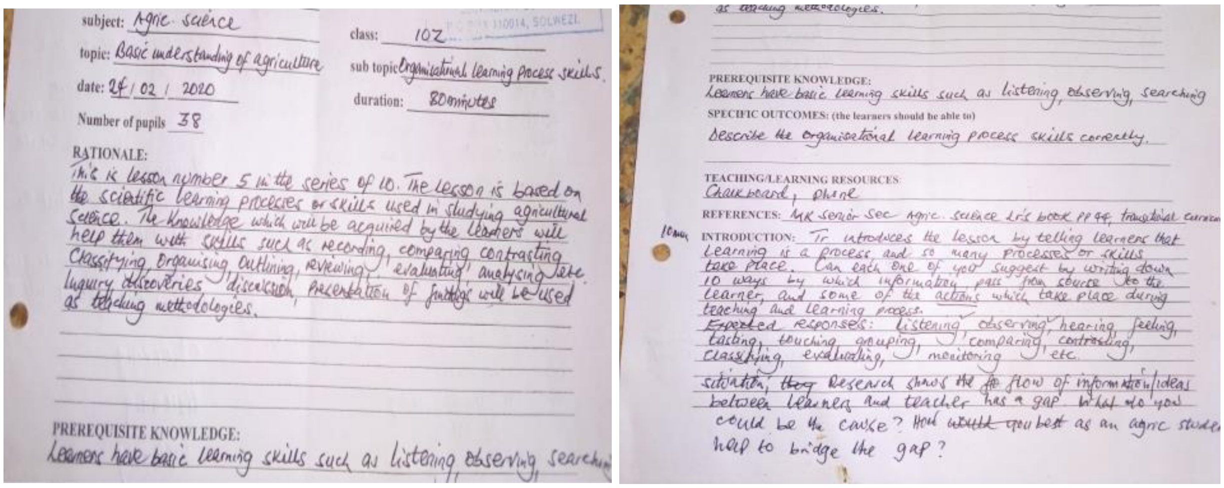


Figure 44: Lesson Plan Formats in Agricultural Sciences at both Junior and Senior Levels

The findings reveal undesirable levels of collaboration, plans to handle misconceptions as well as plans to assess learning. The reasons as to why teachers were not able to collaboratively plan could be that they did not read the instructions that accompanied the STEM curricula documents sent to their schools or they read but did not understand how to go about the aspects under discussion. It could also entail that the teachers still wanted to plan individually as they have been doing or rather, they thought engaging in collaborative lesson planning was time consuming for them. The implication of this is that there would be limited ideas on not only the design of lesson activities but also the plan on how to execute these activities. Additionally, the junior level results revealed use of open lesson plan formats whilst at senior level predetermined lesson plan formats were prevalently used as shown in Figure 45.


subject: Agric science
class: 10Z
topic: Basic understanding of agriculture
sub topic: Organisational learning process skills.
date: 24 / 02 / 2020
duration: 80minutes
Number of pupils 38

RATIONALE:
This is lesson number 5 in the series of 10. The lesson is based on the scientific learning processes or skills used in studying agricultural science. The knowledge which will be acquired by the learners will help them with skills such as recording, comparing contrasting classifying, organising, outlining, reviewing, evaluating, analysing etc. Inquiry discoveries, discussion, presentation of findings will be used as teaching methodologies.

PREREQUISITE KNOWLEDGE:
Learners have basic learning skills such as listening, observing, searching

SPECIFIC OUTCOMES: (the learners should be able to)
Describe the organisational learning process skills correctly.

TEACHING/LEARNING RESOURCES:
Chalkboard, phone

REFERENCES: MK Senior Sec Agric. science Lr's book pp 44, transitional curriculum

10min INTRODUCTION: Tr introduces the lesson by telling learners that learning is a process and so many processes or skills take place. Can each one of you suggest by writing down 10 ways by which information pass from source to the learner, and some of the actions which take place during teaching and learning process.
Expected responses: listening, observing, hearing, feeling, tasting, touching, grouping, comparing, contrasting, classifying, evaluating, monitoring etc.
situation; Research shows the flow of information/ideas between learner and teacher has a gap. What do you could be the cause? How you best as an agric student help to bridge the gap?

Figure 45: Agricultural Science Predetermined Lesson Plan

This widely use of predetermined lesson plan formats could suggest that the school through the respective department provided these predetermined lesson plan formats and teachers had no choice but to use them. The implication of using predetermined lesson plan formats posed a hindrance in the teacher's creative abilities as it was difficult for some of them to add aspects not dictated by the rigid format. Additionally, it makes the lesson plan, and indeed planning for lesson, seem less important. In STEM, lesson plan formats may vary depending on the preference of the teacher, subject and learner ability. Therefore, teachers should be left to create lesson plans that will help incorporate personal creativity. However, in as much as teachers should be given the liberty to use an open lesson plan format, the essential lesson elements that would help produce a critical, creative and analytical thinker must not be left out.

Further at junior level the revelation of lesson plans having no plan on how misconceptions were to be handled becomes of great concern because it entails that the learner's conditions were not taken into consideration during the planning process and this could eventually affect lesson implementation and learner curriculum attainment. Learners have different abilities and educational backgrounds. Therefore, their prior knowledge varies from learner to learner. The learner's prior knowledge can be erroneous, illogical and misinformed and thus learners will have alternative conceptions. Alternative conceptions if left unattended to can impede achievement of learning outcomes in the learning process. In order to effectively achieve STEM learning outcomes, possible misconceptions as well as potential errors that may arise in the learning process must be well thought of and an effective method on how to clear them must be planned for well ahead. To effectively develop the skill of planning for these alternative conceptions, teachers need to have a clear understanding of the subject content matter, viewpoints of the learner as well as the influence of the environment and other subject areas.

Furthermore, not incorporating assessment criterion plans at both senior and junior levels raises concern. Putting in place plans of how to assess learning during the lesson is important because that is the only way one can tell whether learning has taken place. There is need for teachers to plan and provide assessment criteria focusing on the key learning outcomes that should be exhibited by learners as indicators of learning progression and achievement. Use of scientific skills (Acquisitive, Organisational, Creative, Manipulative and Communicative) could be of help to plan for assessing learning. Without the assessment criteria, it is difficult for the teachers to evaluate the progress of learning in a learning process and ultimately the attainment of the curriculum intentions. There is therefore need for teachers to plan for assessing learning.

b) *Biology Science*

The Biology lesson planning findings indicated above average collaboration at both senior and junior levels as shown in Figure 46. However, the aspects of handling conceptions and misconceptions were relatively average and below. Further, the findings showed good use of open lesson templates as 67% of senior and 100% of the junior lesson plans employed open lesson templates.

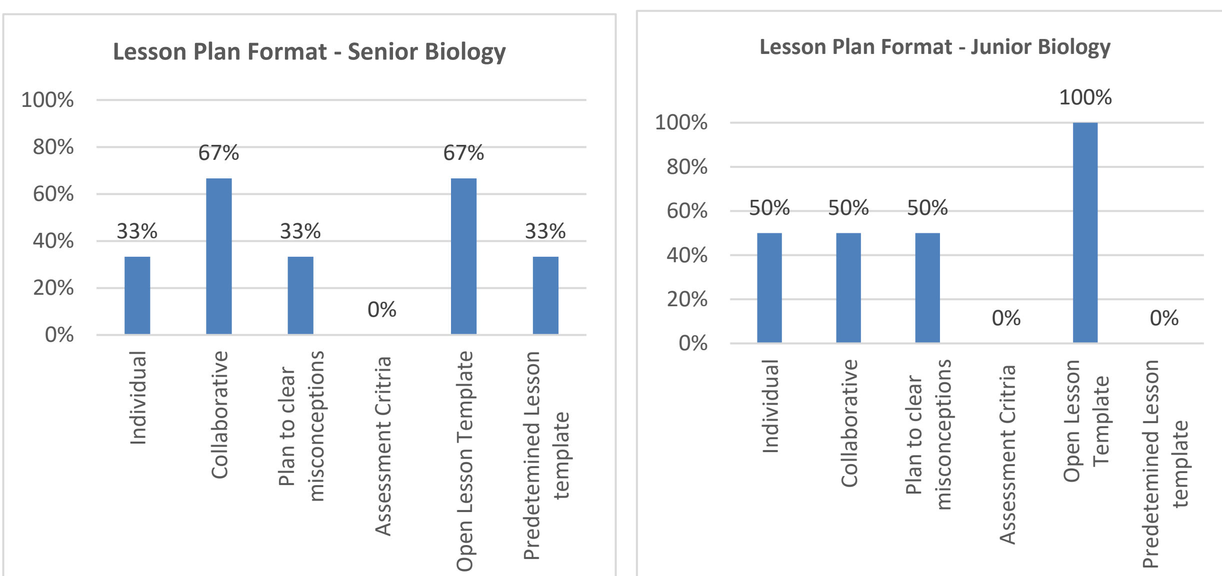


Figure 46: Lesson Plan Format for Biology for Junior and Senior Levels

The considerable collaboration at both senior and junior levels entails that teachers were able to share different perspectives of teaching and learning that aimed at enhancing their content and pedagogical knowledge. The effect of collaboratively planning lessons was seen as most aspects such as topic, subtopic, lesson outcomes and knowledge the teachers needed to excerpt from the curriculum earlier on were considerably done. This could suggest that the concerted efforts in lesson planning helped to understand the Biology curriculum intent. The average plans to handle misconceptions in Biology lessons augment concerns. Not forecasting on how to handle misconceptions should they arise or not could suggest that teachers did not understand their subject content well or that it was just a matter of being casual during lesson planning. This meant that learners' prior knowledge was not taken into account when planning for lessons. And so, this could hinder learners' understanding of concepts during implementation due to lack of consideration of alternate conceptions at planning stage. Additionally, the non-planning for assessment criterion by teachers at both junior and senior levels could have been that they did not know that this was equally an important aspect in lesson planning. It could also point to teachers' lack of constructivist assessment skills as recommended in the STEM Education curriculum. Further, it is worth noting that most of the teachers involved in the survey were trained using positivist curriculum and have been practicing this through their teaching career hence affecting their way of seeing assessment effectively. In STEM teaching and learning, it is essential that teachers plan on how they would assess the learning progression in a lesson. This is significant as it helps to give indicators to the teachers on whether or not the learners would have achieved a learning goal at a particular stage of a lesson. Without the assessment criterion plans, it would be difficult for the teachers to evaluate the progress of learning in a learning process and eventually the attainment of the curriculum intentions. Further, the use of open lesson plan formats entailed that teachers had chances of being creative as they would incorporate freely aspects that would help develop the expected learner.

c) Chemistry

Figure 47 shows the lesson plan format for both senior and junior Chemistry. The results show that there was more collaboration at junior level than at senior level in lesson planning. There was above average and exemplary collaboration in lesson planning as shown by the 50% and 100% at senior and junior levels respectively. However, at senior level, all the lesson plans indicated having plans for misconceptions while at junior level there were no such plans. Regarding assessment criteria, 25% of the lessons at senior indicated how the learning would be assessed during the lesson while at junior level all the lessons had criteria in place for assessment. For the senior level, there was average use of both open and predetermined lesson plan templates whilst at junior level only predetermined lesson plan templates were used.

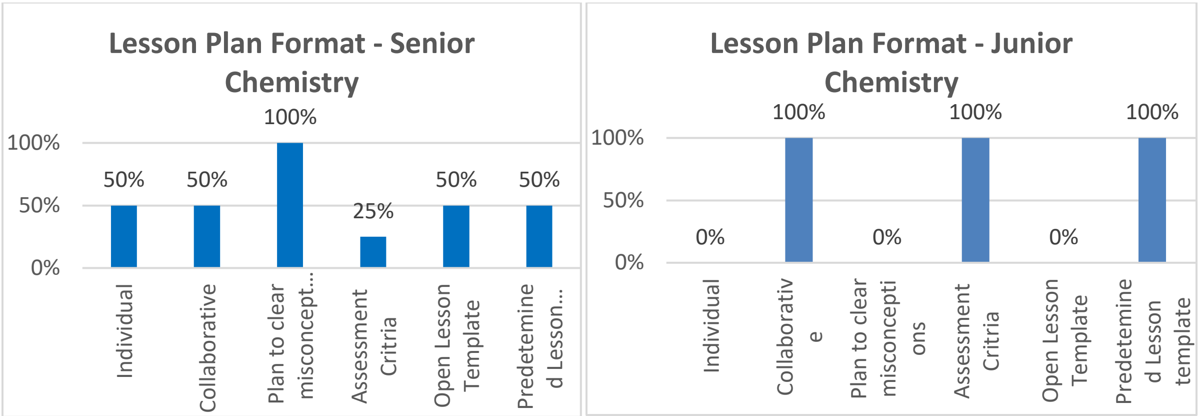


Figure 47: Lesson Plan format for Chemistry at Both Senior and Junior Levels

The average collaboration at both senior and junior levels suggest that teachers were able to not only share various viewpoints of teaching and learning but also skills on how best to execute the lessons. The consequence of collaboratively planning lessons was evidenced by most Chemistry lesson plans having topic, subtopic, lesson outcomes and knowledge in tandem with those prescribed in the curriculum. This could suggest that the teamwork enabled teachers to extract the right information from the curriculum.

The disparities between the junior and senior lesson planning aspects such as plan to clear misconceptions, plan to assess learning and use of lesson templates means that some teachers did not take the lesson planning process with the seriousness that it deserved or that teachers were incompetent in this aspect. Teachers need to plan on how they will make professional judgement on learner performance in every teaching and learning session undertaken by having an assessment criterion plan. In the lesson plans where there was no plan to assess learning the implication is that when the lesson was implemented there would be no continual knowledge on whether the learners were grasping the concepts or not. Additionally, learners have different educational backgrounds and ultimately have varied prior knowledge on various learning aspects. The learner's prior knowledge however, can be erroneous, illogical and misinformed and thus learners will have misconceptions. This means that the junior chemistry lessons which had no plan on how to handle misconceptions did not take learners' condition into consideration. This posed a challenge for the implemented lessons to achieve intended goals as learners could have left the classrooms with the same alternative conceptions and errors they had. Further, as regards to lesson templates, on one hand, the use of rigid predetermined lesson plan formats suggests a hindrance in the teacher's creative abilities as it would be difficult for them to add any other aspects on the lesson plan that would enhance learning. On the other hand, the use of open lesson plan templates provided room for teacher creativity as teachers had the liberty to include essential lesson elements that would help produce a critical, creative and analytical learner. In order to ensure teachers of Chemistry are not at variance in terms of lesson planning proficiencies they need to engage in subject communities of practice which should include lesson planning aspects as content of the professional development activities.

d) Computer Science

In Computer Science, the findings in Figure 48 showed that there was average collaboration during lesson planning as 40 % of lessons plans at senior level and 50% of lessons plans at junior level were collaboratively planned. There were variations at both senior and junior secondary levels in terms of plans to handle misconceptions, assessment criterion plans and the use of lesson plan templates as shown in the figure. At senior, unlike at junior level, there were efforts to plan on how to handle misconceptions as shown by the 40% and none respectively. Additionally, the assessment criterion was not planned for at senior level but there was average indication of planning for assessment at junior level. Further, at both senior and junior levels, there was average indication of the use of open lesson templates as shown by the 60% and 50% respectively.

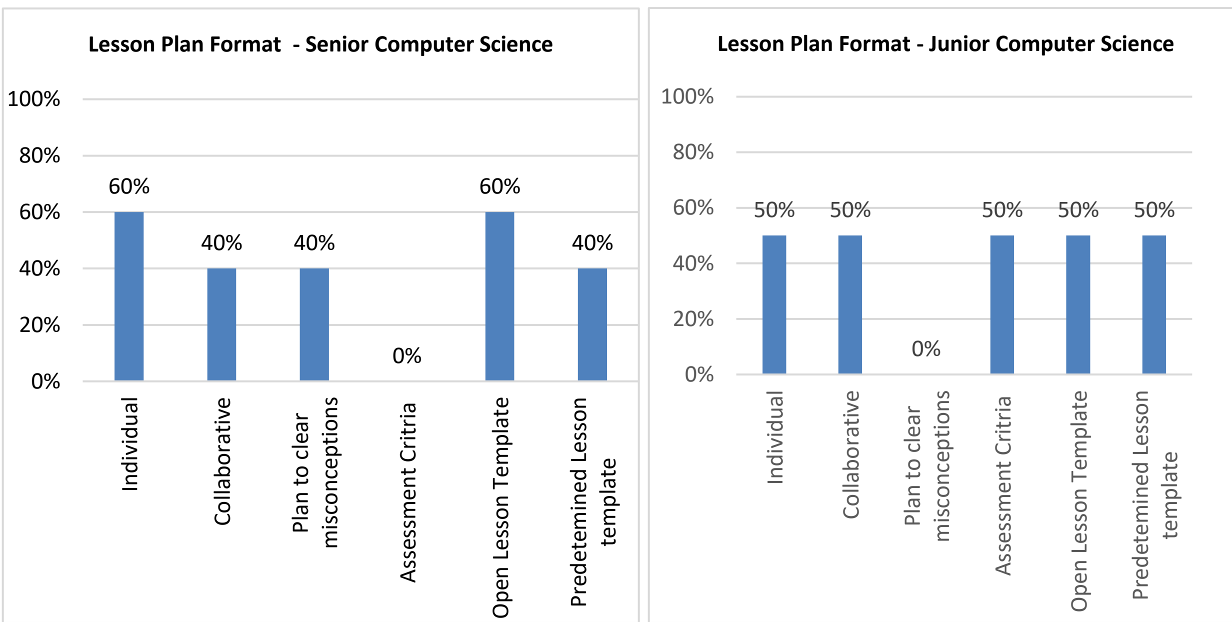


Figure 48: Lesson Plan Format for Computer Science at Both Senior and Junior Levels

Average collaboration during lesson planning at both senior and junior levels meant that there were efforts by teachers to brainstorm creative ideas that were helpful in meeting the diverse needs of the 21st Century learners. Teacher collaboration suggested a positive impact on learners' achievement as it not only allowed teachers to have an in-depth understanding of curriculum aspects but also help the teachers to explore various effective ways of implementing the lessons.

The variations between the senior and junior lesson planning aspects of planning on how to handle alternative conceptions, assessment criteria and use of lesson templates could mean that the teachers had inadequate competencies, skills and value in the area of lesson planning. It is imperative that teachers plan on notable key indicators that would help them assess the learning progress as the lesson proceeds. In the lesson plans where there was no plan to assess learning the implication is that when the lesson was implemented there would be no constant checking on whether the learners comprehended the lesson concepts or not.

The diversity of the experiences that learners come with during the lesson entails that learners have varied conceptions on particular concepts. Some of these conceptions may be incorrect, and thus the need to clear them. Therefore, teachers need to plan on how to handle the responses and reactions that learners are likely to present in the lesson. Further, as regards to lesson templates teachers should be encouraged to express as extensively as possible, their plans on how the lessons would flow, instead of using the predetermined template. To mitigate these disparities Computer Science SBCPD activities should encompass lesson planning aspects.

e) Design and Technology

In Design and Technology there was remarkable and average collaboration at senior and junior levels as shown by the 100% and 50% scores respectively. Efforts on planning on how to handle misconceptions were more pronounced at senior level (67 %) but less at junior level (33 %). Plans for assessing learning were below average for both senior and junior level lessons as can observed from Figure 49. In terms of lesson plan templates at both senior and junior secondary levels, the use of predetermined lesson plan templates was predominant as shown in Figure 41.

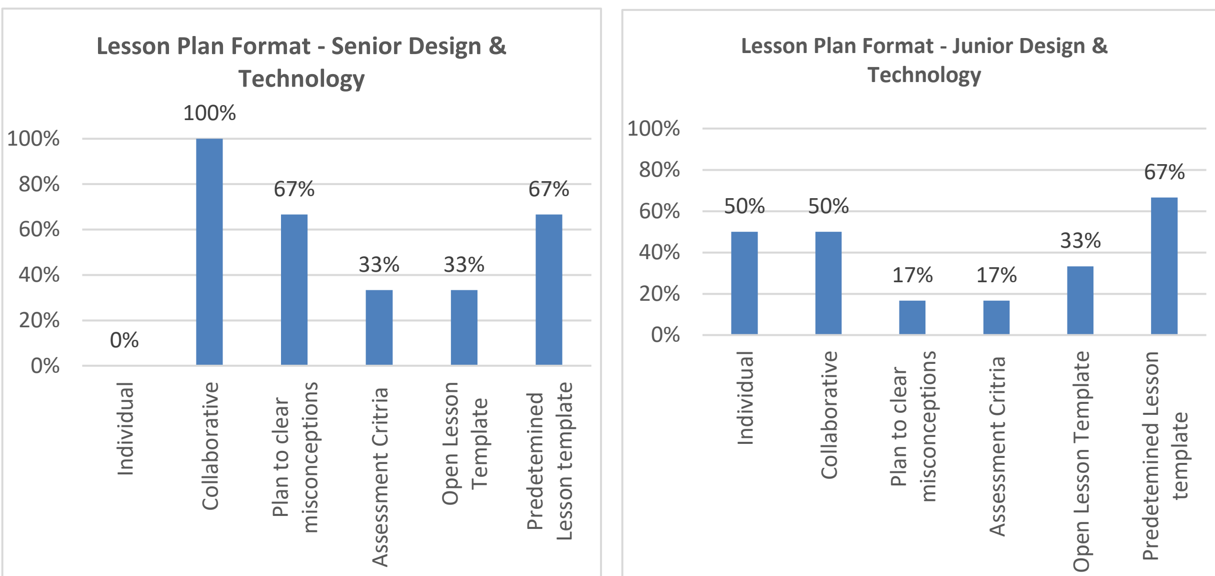


Figure 49: Lesson Plan Format for Design and Technology at Both Senior and Junior Levels

The remarkable collaboration in Design and Technology meant that teachers were able to share diverse knowledge and strategies aimed at enhancing their content and pedagogical knowledge. From initial teacher training, teachers are equipped differently in terms of content and pedagogy hence the need to collaboratively plan lessons. Additionally, STEM advocates for development of learners who are critical, creative and analytical thinkers. To do so, teachers must also be critical and creative in their planning hence, collaboration can help to brainstorm creative ideas in order to select suitable tasks and activities that will better help meet the diverse needs of STEM learners. Teacher collaboration would positively impact on learners' achievement as it will not only allow teachers to have an in-depth understanding of curriculum aspects but also help the teachers to explore various ways of implementing the curriculum. The less efforts shown, to handle misconceptions at junior level meant that the learners' alternative conceptions and bottlenecks that would impede their learning were not taken into consideration. This implies that there would be no tailor-made feedback if misconceptions arose during the implementation process. Having no plans to assess learning at both senior and junior levels raises concerns. The immediate way of ascertaining whether learning takes place during the lesson is by assessing learning during the learning process. Therefore, it is imperative that plans for assessing learning are well stipulated on the lesson plan in order for the teacher to evaluate level of understanding at each stage. This can also inform whether learners have the relevant pre-requisite knowledge and whether to move on to the next stage of the lesson or not. The lack of planning to assess learning could have been as a result of inadequate teacher knowledge and skills on how to plan for formative learning assessment in a lesson and what indicators to use as a checklist. The implication of not having assessment criterion plans is that it would be difficult to know whether the learners comprehended the lesson concepts at the point of lesson implementation.

In terms of lesson plan templates, more predetermined templates were used at both senior and junior levels as epitomised in Figure 50.

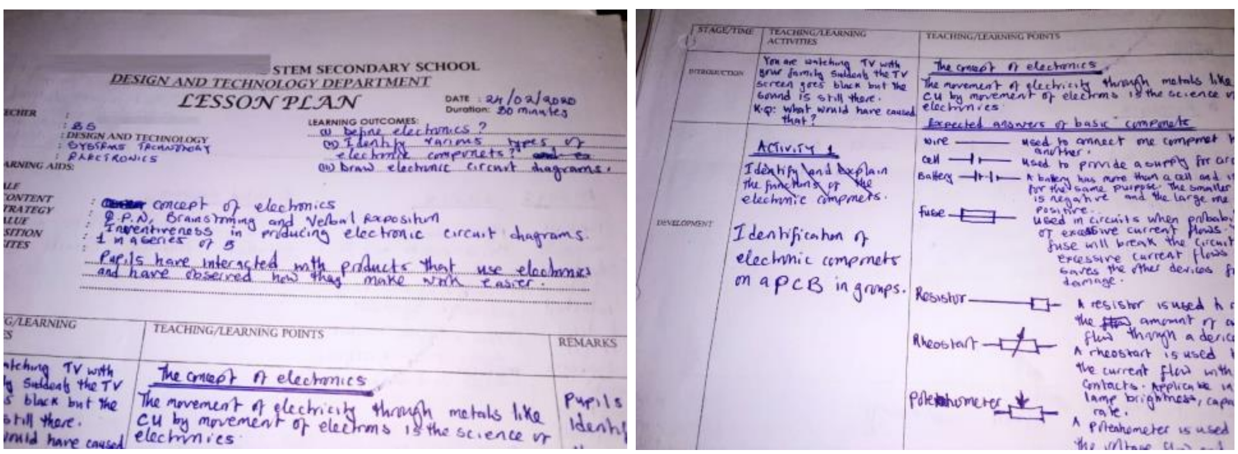

[redacted] STEM SECONDARY SCHOOL
DESIGN AND TECHNOLOGY DEPARTMENT
LESSON PLAN
DATE : 24/02/2020
Duration: 80 minutes
LEARNING OUTCOMES:
DESIGN AND TECHNOLOGY
concept of electronics
Pupils have interacted with products that use electronics and have observed how they make work easier.
TEACHING/LEARNING POINTS
REMARKS
The concept of electronics
The movement of electricity through metals like CU by movement of electrons is the science of electronics
STAGE/TIME
TEACHING/LEARNING ACTIVITIES
TEACHING/LEARNING POINTS
INTRODUCTION
DEVELOPMENT
Activity 1
Identify and explain the functions of the electronic components.
Identification of electronic components on a PCB in groups.

Figure 50: Design and Technology Predetermined Lesson Plan Format

The prevalent use of printed predetermined lesson plan formats might suggest this phenomenon is perpetuated by school administrators and Standards Officers who encourage uniformity in lesson planning and so teachers tend to have no choice but to use them. The implication of using predetermined lesson plan formats is that it poses a limitation in the teacher's creative and innovative competences as the rigid templates in most cases do not have enough space to include such. It is recommended that teacher capacity building trainings in Design and Technology, both at school level and otherwise, should include lesson planning.

f) Hospitality and Tourism

The Hospitality and Tourism findings in Figure 51 indicated that lesson planning, at senior level, was collaboratively done with plans to handle misconceptions as well as to assess learning at each stage of the lesson as all these three aspects had result scores of 100%. However, there was predominant use of predetermined lesson plan templates as opposed to open ones. At junior level, there was no collaborative planning, no plans on how to handle misconceptions and assessment criteria during lesson planning. There was, however, use of open lesson templates at this level.

Figure 51: Lesson Plan Format for Hospitality & Tourism at Both Senior and Junior Levels

At senior level, the remarkable collaborative lesson planning, the planning on handling misconceptions and assessing learning means that teachers had suitable proficiencies that helped them meritoriously plan for the lessons. Through sharing ideas in collaborative lesson planning, teachers shared an enlarged repertoire of subject matter and institutional knowledge thereby, increasing the opportunity to deliver good lessons. Not planning on how misconceptions were to be handled alludes to teachers not supporting learning and hence, making learners to exit lessons with inexplicit information. In order to effectively plan for misconceptions, teachers need to ascertain and understand learners' conditions.

g) Mathematics

Figure 52 shows the levels of collaborative planning, planning for misconceptions and assessment as well as types of lesson plan formats used. On one hand, lesson planning as regards to Mathematics, showed remarkable results at both senior (80 %) and junior (83 %) levels in terms of collaboration. On the other hand, results showed that during the planning stage no single senior Mathematics lesson had a plan on how to handle misconceptions whilst at the junior level the plans on how to handle misconceptions were above average. There was indication that at both senior and junior levels, half the lessons were planned using open and the other half using predetermined lesson templates.

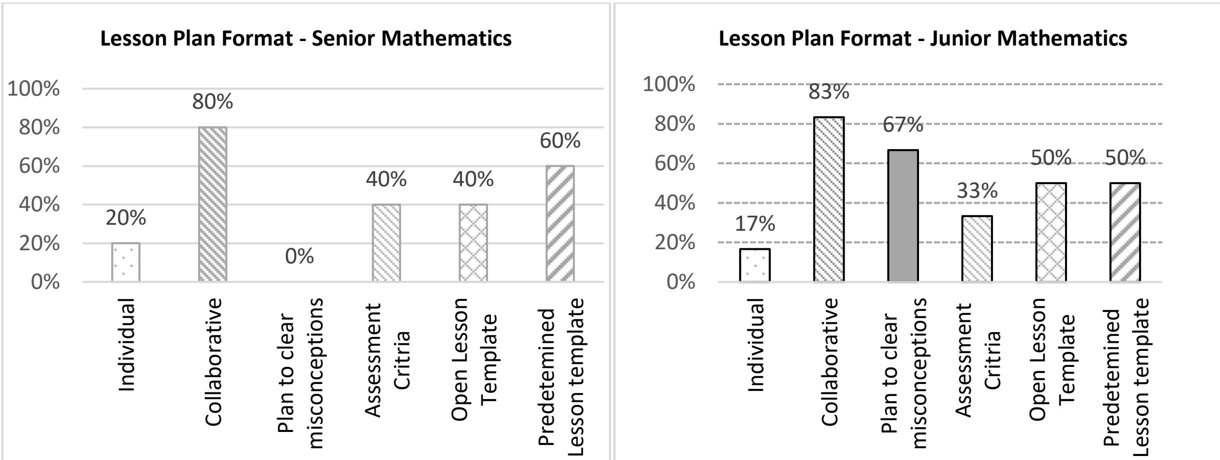


Figure 52: Lesson Plan Format for Mathematics at Both Senior and Junior Levels

The remarkable collaborative planning at both junior and senior levels was a good professional endeavour. It means that teachers of Mathematics were able to share knowledge as well as teaching and learning approaches amongst themselves that would lead to effective lesson implementation.

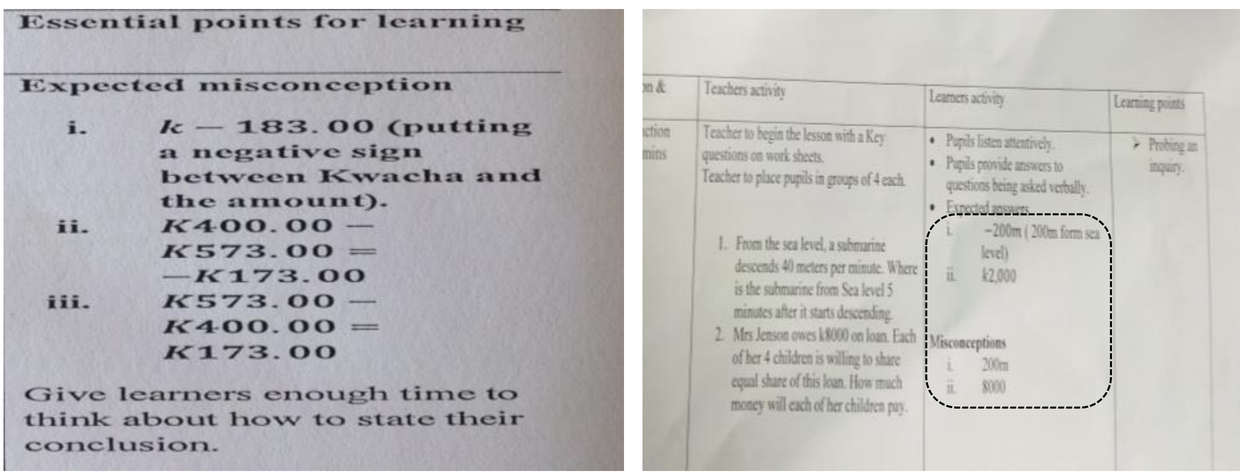


Figure 53: Lesson Plan Extracts with Misconception Plans

At junior, unlike senior level, there were plans on alternative conceptions that would arise as typified in Figure 53. However, it was observed that some misconceptions might have been created by teachers as seen in the framed plan on the right of Figure 53 and carry with them to the lesson implementation. Therefore, to effectively plan for alternative conceptions teachers need to have; comprehensive understanding of the subject matter, prior learner knowledge on the subject matter, the learning environment, learners' context on societal and cultural beliefs to ascertain what possible misconceptions may arise.

Physics

The findings in Figure 54 show that there was notable indication of collaborative lesson planning at both senior (100%) and junior (75%) levels. As regards to plans for handling misconceptions, the senior level lesson plans indicated outstanding scores compared to the junior level. For both levels plans for assessment criteria were not clearly stated in the lesson plans. However, there was remarkable use of the open lesson templates at both senior and junior levels.

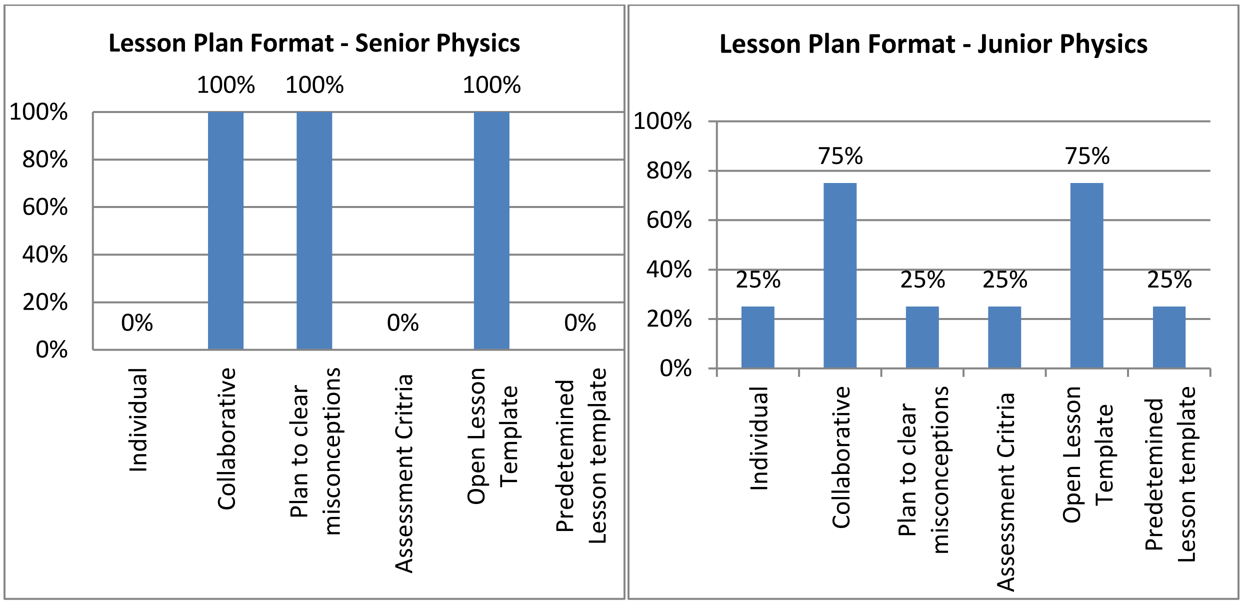


Figure 54: Lesson Plan Format for Physics at Both Senior and Junior Levels

In Physics lesson plans it was observed that collaborative planning, planning for misconceptions and use of free-flow of lesson planning were quite predominant at senior level where as at junior level it is only collaborative planning and use of open lesson templates that were highly scored. This implies that teachers took time to intensively study the teaching and learning materials as they planned for their lessons. However, lack of planning for assessment is still a problem even for Physics teachers. This could result in having difficulties to ascertain the levels of understanding by the learners and to inform the next decision whether to proceed with the lesson or not otherwise the lesson would end up being teacher-directed.

Summary of Preliminaries to Planning for Lesson in Relation to Curriculum Implementation

As shown in Figure 55, generally, across all subjects there was above average collaborative (65%) lesson planning and average use of open (51%) and predetermined (49%) lesson plan template. However, plans to clear misconceptions (37%) and assess learning (20%) were both below average.

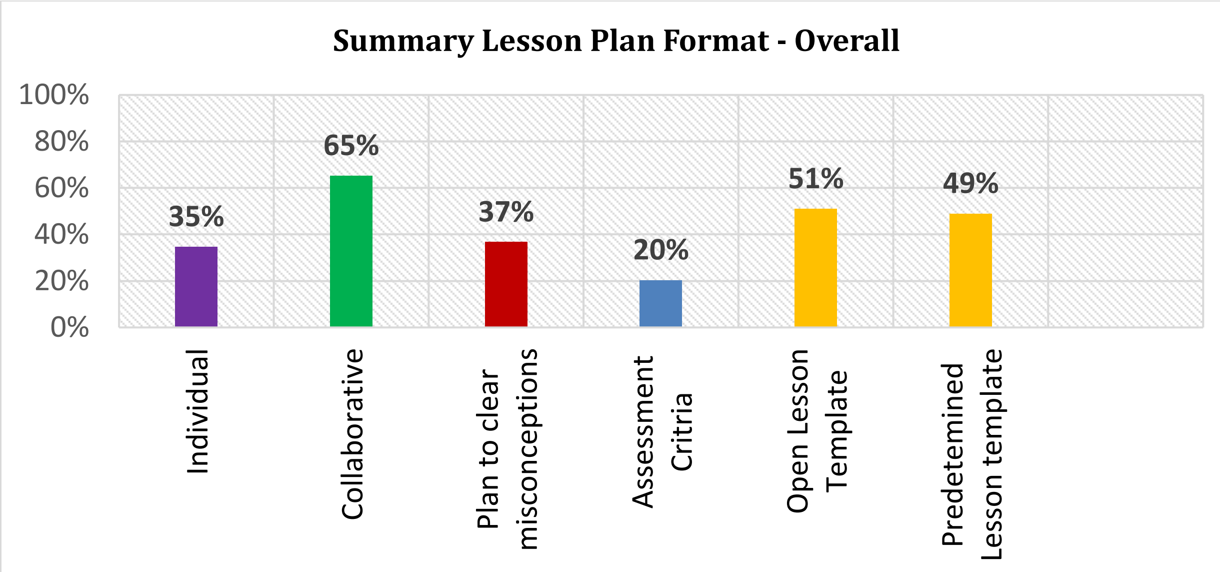


Figure 55: Preliminaries to Planning for Lesson in Relation to Curriculum Implementation

The above average indication of collaborative lesson planning across all the STEM subjects means that majority of the teachers are engaging in consultative sharing of knowledge on teaching and learning strategies to improve classroom practice. Below average plans on how to handle misconceptions and assess learning raises a lot of concern. Not planning to handle misconceptions as well as not having plans to assess learning impedes achievement of learning outcomes as the delivered lessons may progress without knowledge of whether learners were grasping the concepts or not. The use of predetermined lesson plan templates was an aspect of concern across all the subjects. In STEM, lesson plan format may vary depending on the subject, however, teachers should be given the liberty to use lesson plan formats that incorporate essential elements needed to produce a critical, creative and analytical learner. Should predetermined lesson plan templates be used, a soft copy would be better to enable teachers to add as much text and figures as possible to enrich their planning for the lessons.

ii. Content in Planning for Lesson in Relation to Curriculum Implementation

Planning for Lesson Rationale

This section presents and discusses findings relating to content in planning for lessons focusing on the rationale aspect. The flow of presentation and discussion will be like the ones above where each subject will be discussed in detail. Rationale is one aspect in lesson planning which tends to justify why a lesson should be taught to learners. It, therefore, outlines the significance of the lesson. It is a general statement that broadly emphasises the applicability and usefulness of the content of the lesson to the learners either in the present or in the future. The rationale, therefore, affords the teacher an opportunity to see why the lesson must be taught. Furthermore, it shows how the teacher understands the knowledge and skills to be taught in the lesson. The key elements in a lesson rationale are the content, value, method and position. The content is the outline of what is to be taught and learnt in a lesson. The value is the relevance of what should be learnt in the lesson. The methods are approaches or strategies that may be used to deliver the lesson and how the lesson outcomes may be attained with that approach. Finally, the position indicates the location of the lesson out of the total number of the planned periods for teaching a particular unit or topic where this lesson is located.

Lesson rationales are essential in STEM constructivist lesson plans as they provide the significance of particular lessons. A well written lesson rationale would be an indication that a teacher has understood the curriculum intentions. Therefore, in order to meet curriculum demands, development of well thought out rationales should be part of the lesson planning process. A lesson rationale as a justification needs to have learner needs planned through the 'what and how'. In the viewpoint of this research, the findings and analyses of STEM lesson rationales included the content, importance, methods and lesson location. The findings and analyses across grades and subjects were:

a) Agricultural Science

Figure 56 shows the conformity results of the rationale aspects in the Agricultural Science lesson plans observed. The findings showed that at senior level 67% of the lesson plan rationales had content and importance indicated. It was further observed that all the lesson plans at senior level had indicated the position of the lesson in the rationale. However, the aspect of methodology was not properly indicated. For junior level lesson plans, the importance and methodology were indicated in the rationale. Conversely, the content and position were not indicated at all in the rationale.

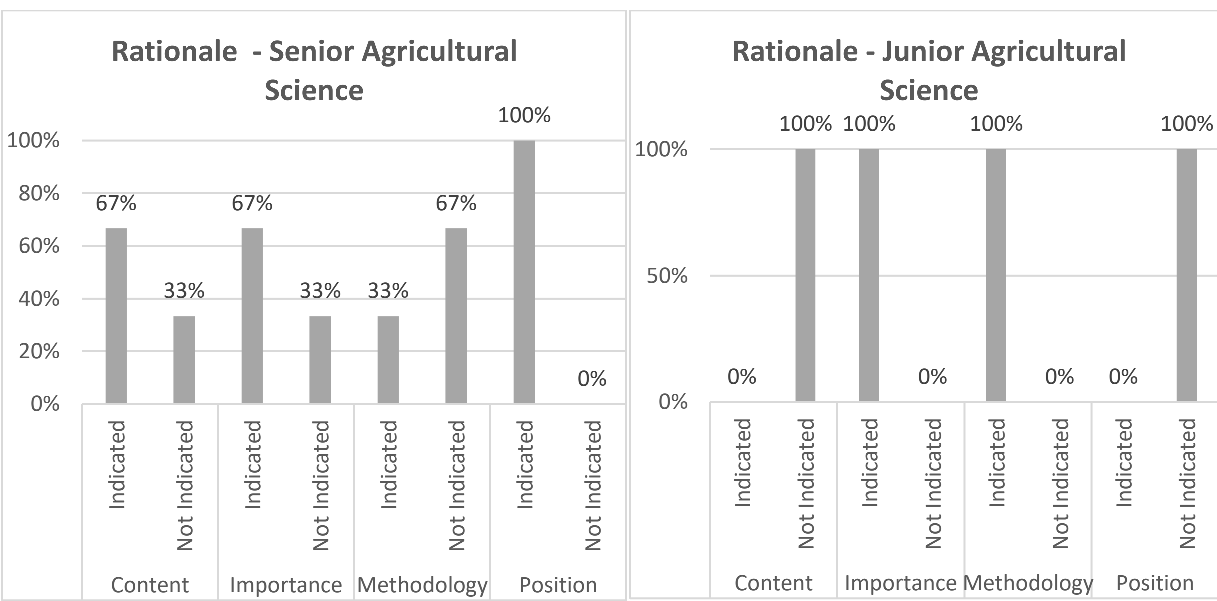


Figure 56: Rationale for Agricultural Science at Both Senior and Junior Levels

The STEM Education Curriculum recommends, amongst others, the following methodologies: Inquiry Discovery, Problem Based Learning, Masterly Learning, Research Approach, 5Es (Engage, Explore, Explain, Elaborate, and Evaluate), Approach, Subjective Learning, Experimental and Field Work. It was, however, found in the survey that the teachers planned to use only Inquiry Discovery, Discussion and Group Work. Out of all the methods indicated, Inquiry was the only method amongst the suggested curriculum methods. This could mean that there was struggle in identifying the rightful methods to use to teach the lesson concepts. The findings therefore, show that while there was understanding of what should constitute a rationale, what should be explained in depth was still a challenge. Additionally, there seems to be a misconception of viewing Group Work as a methodology.

The Agricultural Science findings showed that at senior level there was above average indication of the content and importance whilst the methodology aspect was far below average. Additionally, all the senior lesson plan rationales had the location of the lesson indicated. The attempt shown to indicate the importance of the rationale is of paramount importance as it implied that there were efforts in trying to bring relevance of learning Agriculture Science. In this contemporary world there are unprecedented demands on Agricultural and natural resources, and so Agriculture Science in STEM, if taught and learnt effectively, can help achieve the Sustainable Development Goal (SDG-2) which aims at ending hunger, achieving food security and improving nutrition through promotion of sustainable inclusive agriculture in Zambia. Therefore, well-developed lesson rationales that incorporate value aspects could be a starting point in helping to attain these aspirations. Despite the importance being indicated in the lesson rationales all the Agricultural Science rationales had inadequate importance information. A case in point is the rationale below:

> *"This lesson is number 5 in a series of 10. The lesson is based on the scientific learning process skills used in studying Agricultural science. The knowledge which will be acquired by the learners will help them with skills such as recording, comparing, contrasting, classifying, organizing, outlining, reviewing, evaluating, and analyzing. Inquiry discovery…"*

This rationale was inadequate because instead of ordinary mentioning of scientific skills there could have more elaboration on why the acquisition of these scientific skills was important and how they could be used in everyday life. Further, at junior level, none of the lessons indicated the content aspect of the rationale and the position but there was remarkable indication of the methods and lesson importance. This remarkable indication of methodology meant that teachers were able to plan on how the lesson concepts were to be learnt. The implication of this is that, learning methods if well planned for can influence the teaching and learning activities that would be used in the lesson. In STEM Education, effective teaching methods are those that should encompass constructivist tenets. For a lesson to be well planned, a teacher needs to have adequate understanding of curriculum content knowledge and teaching & learning approaches for them to effectively plan what and how the information will be learnt. To ensure improvement of this, Continuous Professional Development and capacity building of teachers at all levels is inevitable.

b) Biology science

The level of compliance of Biology lesson plan rationales are shown in Figure 57. The findings revealed that none of the senior lessons had the content aspect indicated while the junior lesson plans had average indication. In addition, only 33% of the planned lesson rationales had methods indicated at senior level whereas none were shown at junior level. However, the importance and position aspects, at the point of planning, at both senior and junior were outstanding (100%).

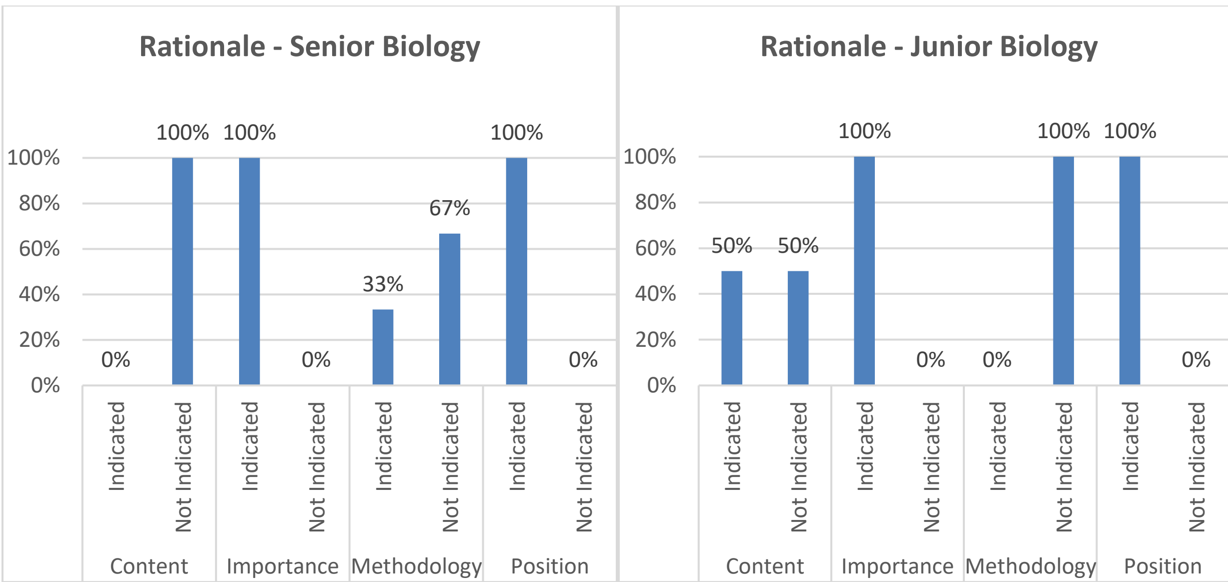


Figure 57: Rationale for Biology at Both Senior and Junior Levels

The teaching & learning methods indicated in the Biology lessons rationales are shown in Table12

Table 12: Methodologies Indicated In Biology Science Lessons

Methodology	
Indicated on Lesson Plan Rationale	**Suggested in the Curriculum**
Brainstorming, Question & Answer, Inquiry Discovery, Discussion, Individual and Group Work	Inquiry Discovery, Problem Based Learning, Masterly Learning, Research Approach,5Es Approach, Subjective Learning, Experimental and Field Work

The absence of content is of great concern because the implication of this is that the extent of lesson content to be taught and learnt would not be known and this could lead to either information scarcity or overload in the lesson plan. On one hand, may lead to deprivation of Curriculum content while on the other hand, information overload may lead to inclusion of knowledge content outside that which is outlined in the curriculum. However, the remarkable representation of the importance aspect entails that there were attempts to connect lessons to real life and help in addressing the needs of contemporary society. Further, despite the importance being indicated in the lesson rationales all the Biology rationales had inadequate importance information. A case in point is that of rationale below:

> "*This is the fourth lesson out of four, aimed at equipping learners with skills that will enable them relate and communicate the relationship between cell structure and function of specialized cells in both plants and animals. The lesson will be delivered through individual and group work"*

For the rationale case above, the importance of learning cell structure and its functions was not explicitly elaborated. There is vast relevance of cells in everyday life which range from: more effective local medicines, improved qualities in plants and animals (genetic engineering), forensic pathology (post-mortem), climate change effects and biotechnology, amongst others, that could be obtained through increased understanding of cell structure and how cells function in living organisms. A good rationale should have an explicit connection as to how the knowledge would be applied in everyday life and there should be mention of the expected proficiencies to be realized in the learning process. The importance aspect of the rationale should include the direct relevance of the lesson to everyday life by stating the reason as to why learning about a particular concept is vital to present day and future societies. Being cognizant that most STEM subject concepts have vast relevance in this technological era, it is important to contextualize their significance. In doing so the conceptual knowledge would be closely linked with the immediate local environment and make certain of its applicability.

As for the planned teaching & learning methods in the Biology lessons the most prevalent out of all the methods suggested in the curriculum was inquiry. Planning to use inquiry methods entails that there was understanding that in STEM, methods that engage learners in deeper understanding of concepts needed to be utilized. The implication is that the planned lesson activities will be influenced by the inquiry method hence, the learning activities would progress from curiosity into critical thinking and deeper levels of understanding Biology concepts. Inquiry helps learners to investigate using structured, guided, open or confirmatory activities. Therefore, whilst inquiry was planned to be used, the type of inquiry method should be specified to enable lesson activities to be planned effectively.

c) Chemistry

Figure 58 shows the results on the compliance of the rationale aspects being indicated on the lesson plans in Chemistry at senior and junior levels. At senior level there was above average indication (75%) of the content aspect. Position of the lessons was indicated on all the rationales at both junior and senior levels. The junior lesson showed outstanding results of lesson rationale aspects indication as the content and importance 100%. Conversely, there was average indication of methodologies at senior level and none at junior level.

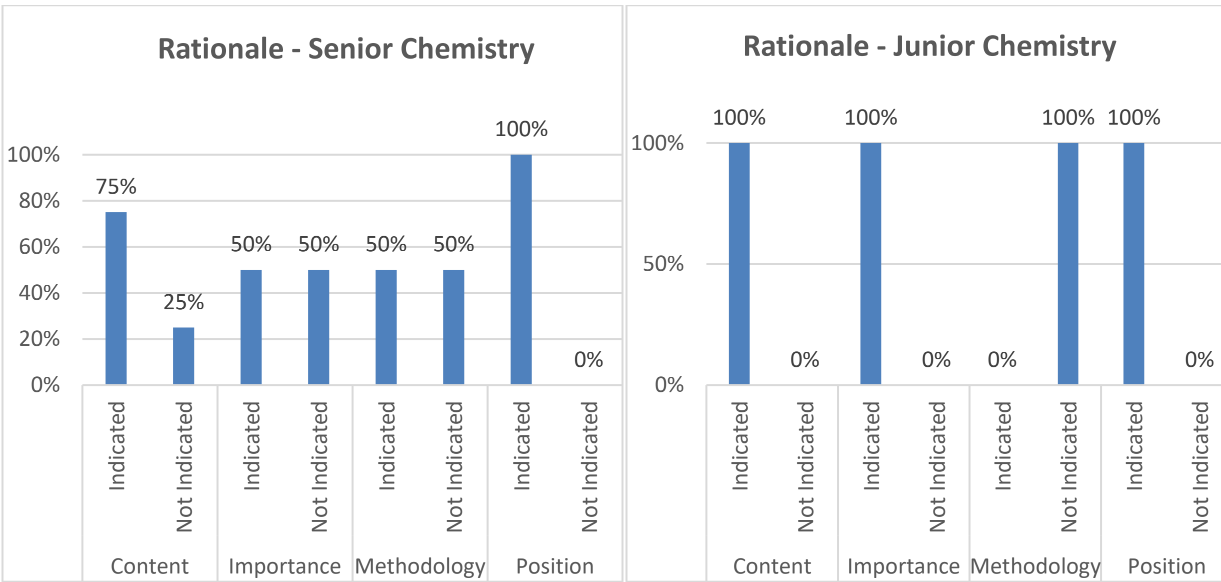


Figure 58: Rationale for Chemistry at Both Senior and Junior Levels

In the 2019 STEM Transitional Curriculum the proposed teaching methodologies to be used in STEM Education learning are: Inquiry Discovery, Problem-Based Learning (Problem-Solving), Masterly Learning, Research Approach, Cooperative Learning, Subjective Learning, Experimental and Field Work. The Curriculum suggests that employing these methodologies would enhance acquisition of skills and values, and creation of the productive learner through critical thinking, creativity and analysis which are 21st Century skills. However, the methodologies observed on the lesson plan rationales in Chemistry were; Discovery, Discussion, Problem-Based, Question & Answer, Experimentation, Inquiry Discovery, Group Work, Group Discussion. It is perceptible that teachers have a challenge to distinguish what exactly a teaching methodology is from the above list. This is so because definitely group work, discussion and question & answer are not teaching methodologies per se, but strategies.

In Chemistry the results showed indication of the content, importance and position aspects on lesson rationales with outstanding results in the case of the Chemistry junior level. This meant that the rationale constituents were understood, however, the content and importance aspects were not adequately elaborated as shown in the cases below:

Case1: *"Scientific skills are skills which can be developed in learners. In this lesson learners will help formulate the hypothesis, they will explain other scientific skills such as inference, inquiry, hypothesis, experimentation, observation, data collection, conclusion and evaluation. Learners should develop scientific skills in order to appreciate science and practice science in their day to day life. The method used..."*

For the rationale in case 1, despite it having the content, the importance was not adequate as there was no precise explanation as to the relevance of learning about these scientific skills to present day community activities. A good rationale should have a justification on not only how the knowledge would be applied in everyday life but also mention the expected proficiencies to be realized in the learning process. This justification should be in line with the content knowledge and so the content part of what is to be taught and learnt should also be explicit in the rationale. The second case below is of a rationale that did not have explicit content.

Case2: "This lesson is the third in a series of seven. It will help the learners understand the process of diffusion. The learners will learn about factors affecting diffusion through discussing and sharing of ideas in groups and later as a class. The approach used will be discovery..."

The rationale in case two does not give intricate details on what exactly was to be learnt. If the knowledge is explained adequately the link to the relevance would equally be easily established. The reason for not adequately indicating content and concept is that there could have been little understanding on how much to write in a rationale. The implication of this is that there would be chances of planning for lessons which would have information and proficiencies outside the dictates of the Curriculum hence ultimately impeding the realization of its intentions.

Further, as regards methods, there was less than average indication in Chemistry lesson plans. In the case of few rationales that had the method aspects indicated on the lesson plans, there was use of '*question & answer'* listed as methods of which it is not. This implies that there could have been misunderstanding between teaching & learning methods, strategies and styles. If learning activities have to be planned in a constructivist way, it is important that these aspects be understood and differentiated clearly as this would help in the effective implementation of the Curriculum. It was, however, noted that the use of inquiry and problem-based learning indicated that there was conformity with methods suggested in the Curriculum. Inquiry and problem-based learning imply that the activities that would be planned in line with these methods will involve continuous engagement, improvement of interpersonal skills and connection on how to address real life challenges which are desirable intentions of the STEM Education Curriculum. The implication of this is that understanding of methods to use in STEM Education entails that, lessons would be planned in such a way that learning would progress from inquisitiveness into critical to analytical thinking hence achieving blooms higher levels of knowledge acquisition which are consistent with

21^{st} Century proficiencies. Therefore, it is recommended that the use of these and many more constructivist methods be encouraged through enhanced professional development meetings at all levels.

d) Computer Science

Figure 59 on one hand, shows the Computer Science findings at senior level in terms of the rationale showed that 40% of the lessons had content and methodology aspect, 60% had importance and 80% had the position aspect. On the other hand, there was 50% indication on all the rationale aspects at junior level.

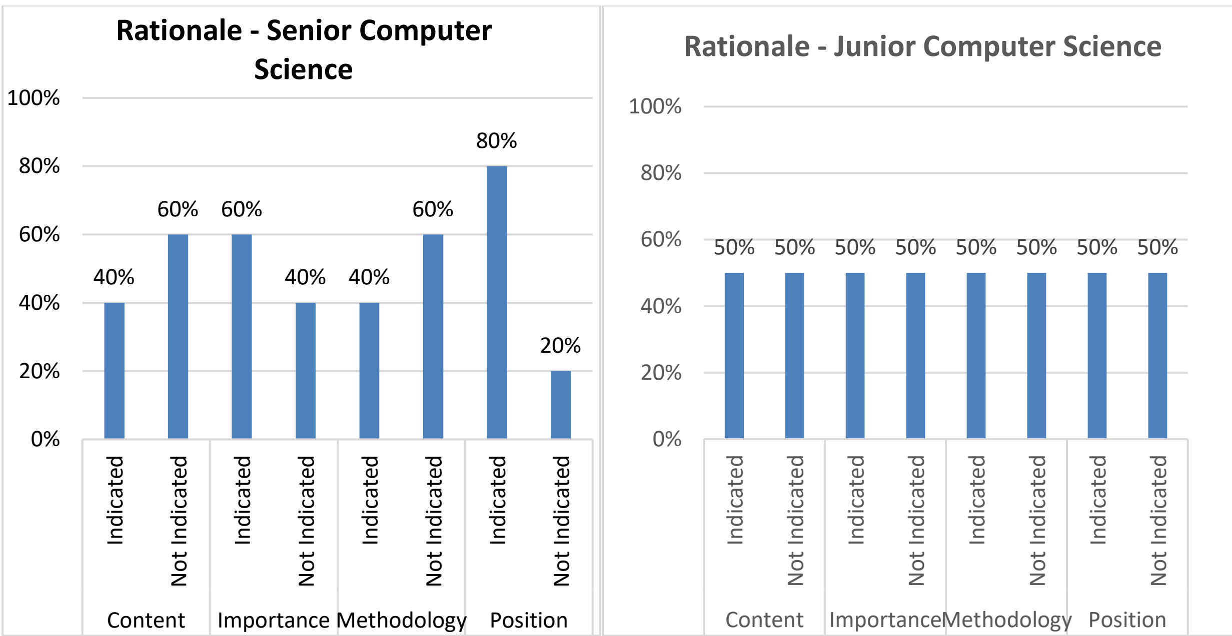


Figure 59: Rationale Senior and Junior Computer Science

The methodologies indicated on both junior and senior computer science lesson plan rationales were as shown in Table 13.

Table 13: Methodologies Indicated in Computer Science Lessons

Methodology	
Indicated on Lesson Plan Rationale	**Suggested in the curriculum**
Discovery, Group discussion, Inquiry, Problem-Solving, Hands-on	Inquiry discovery, problem based learning, masterly learning, research approach,5Es approach, subjective learning, experimental and field work

The findings in Computer Science showed that there was average indication of the content, method and importance aspects of the rationale with above average indication of the position at senior level and average indication at junior level. A case in point of Computer Science lessons that had inadequate content and importance amongst others was:

> "*In this lesson we will look at [I]nformation [and] [C]ommunications [T]echnolog[y] to enhance the learners to be creative, self-reliant and appreciate the importance of communication in life and entrepreneurships*..."

This rationale did not explain what Information and Communications Technologies were to be explored in the lesson, the skills that would be acquired and how these would be applicable and useful in everyday activities considering the context in which learning was to take place. The reason for not including adequate content in the rationale could be that there was insufficient understanding of curriculum intentions thereby making it difficult to plan for the content and importance of the lessons. Below are reference cases showing inadequate understanding of the content include rationales from two lessons on computer architecture:

> Case 1: "*In this lesson, we will look at computer memory to help the learners know how the computer stores and accesses information in an orderly manner."*
>
> *Case 2: "Learners will explore the different types of memories in a computer. This will help a learner build high performing computers to be used as research tools."*

The two lesson cases show insufficient information on the depth of the content and so the link to the relevance could equally not be adequately established. For a lesson to be well planned for, a teacher needs to have adequate understanding of curriculum content knowledge of the subject matter for them to effectively plan what and how the information will be learnt. There is need therefore, to capacity build teachers in knowledge of the curriculum in order to enhance their planning skills.

Further, most of the methodologies listed in Computer Science lessons were in line with suggested curriculum methods. This meant that Computer Science lesson activities would be characterized with interactive engagement thereby laying ground for enhancement of attributes needed in modern day and future societies. Therefore, having had excerpted suitable methods showed that there was understanding of curriculum intentions by the teachers. To continue planning for such interactive methods, professional development activities at all levels need to be strengthened.

e) Design and Technology

The results on rationale aspects in Design and Technology are shown in Figure 60. The findings at senior level indicated above average (67%) for all aspects while there was average indication (50%) except for the content aspect which was at 33%.

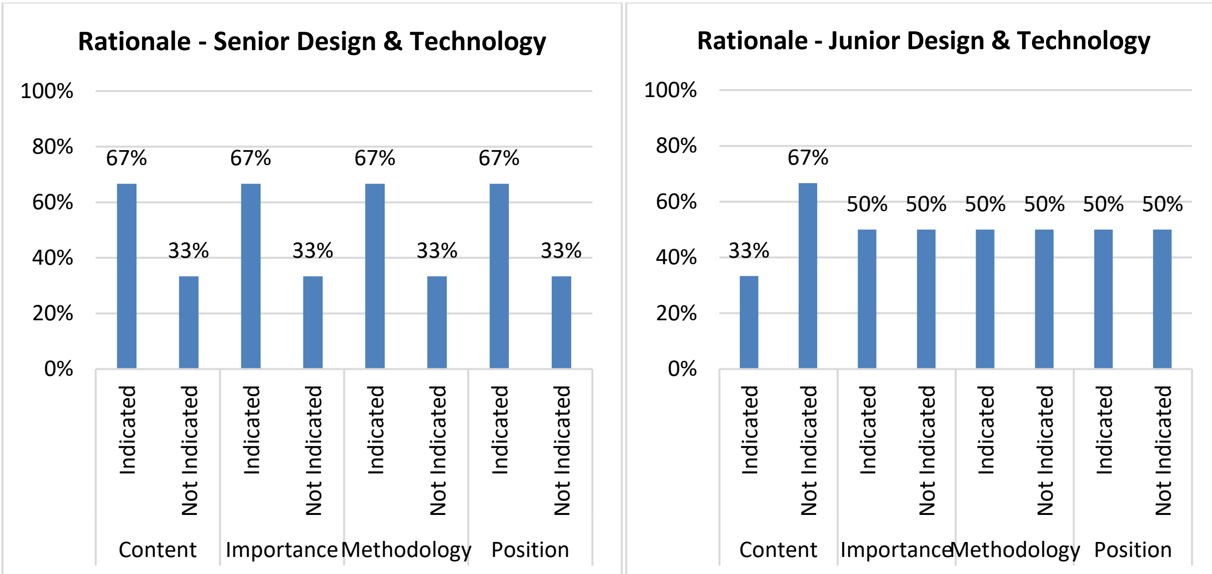


Figure 60: Rationale - Senior and Junior Design & Technology

Table 14 shows the methodologies indicated on both junior and senior Design and Technology lesson rationales.

Table 14 Methodologies Indicated in Design and Technology

Methodologies	
Indicated on Lesson Plan Rationale	**Suggested in the Curriculum**
Brainstorming, Question & Answer, Inquiry Discovery, Group Discussion, Individual Work, Demonstration	Inquiry Discovery, Problem Based Learning, Masterly Learning, Research Approach, 5Es Approach, Subjective Learning, Experimental and Field Work

The results reveal average compliance to indicating the key aspects of the rationale on their lesson plans with senior having above average. This shows that the in Design and Technology lesson plans there was potential to improve on the construction of lesson rationale. However, the lesson plans had inadequate information in these aspects which should have been included. This is illustrated in the following cases:

> Case 1 - "*Content: calculating the rating of resistors in electrical circuits. Value: To help learners to appreciate the functions of resistors in electrical equipment*"

The rationale did not have adequate content knowledge and, therefore, the value was not also explicitly linked to how the knowledge would be applicable in everyday activities. The reason for not including adequate content in the rationale could be that there was insufficient understanding of curriculum intentions thereby making it difficult to plan for the lesson content. However, there were cases were content was sufficiently elaborate as shown in Case 2:

> Case 2 - *"Learners to use principles in graphic design by the use of balance, alignment, repetition, proximity, contrast, space and this could be achieved through group discussion, inquiry discovery, …thus interpreting and communicating graphically the ideas developed"*

The rationale in Case 2 shows appropriate content knowledge, however, it fell short in elaborating the relevance of the lesson to everyday life. The reason for this could be that, teachers do not have adequate knowledge and skills to relate the application of lesson content to everyday life. A good rationale should have validation on not only how the knowledge would be applied in everyday life but also state the expected skills to be realized in the learning process. This validation should be in line with the content knowledge. Therefore, there is need to enhance Teacher Professional Development activities in Design and Technology in order to enhance planning skills.

Further, the methodologies listed in Table 13 showed that, Inquiry Discovery was the only method that was in line with the suggested curriculum methods. This entails that, teachers were unable to incorporate suggested curriculum methods in their plans. The inability to use suggested methods in the curriculum, might imply that there would be no proper direction in the flow of lesson activities in implemented lessons. In order to ensure that teachers of Design and Technology have adequate skills in rationale formulation, Continuing Professional Development activities need to include aspects of rationale understanding and development.

f) Hospitality & Tourism

Figure 61 shows rationale aspects for Hospitality & Tourism lessons observed. The results revealed that there was outstanding indication of content, importance and position aspects at senior (100 %) unlike at junior (0 %) level. However, at junior level, there was remarkable indication of the methodology aspect as compared to the senior level.

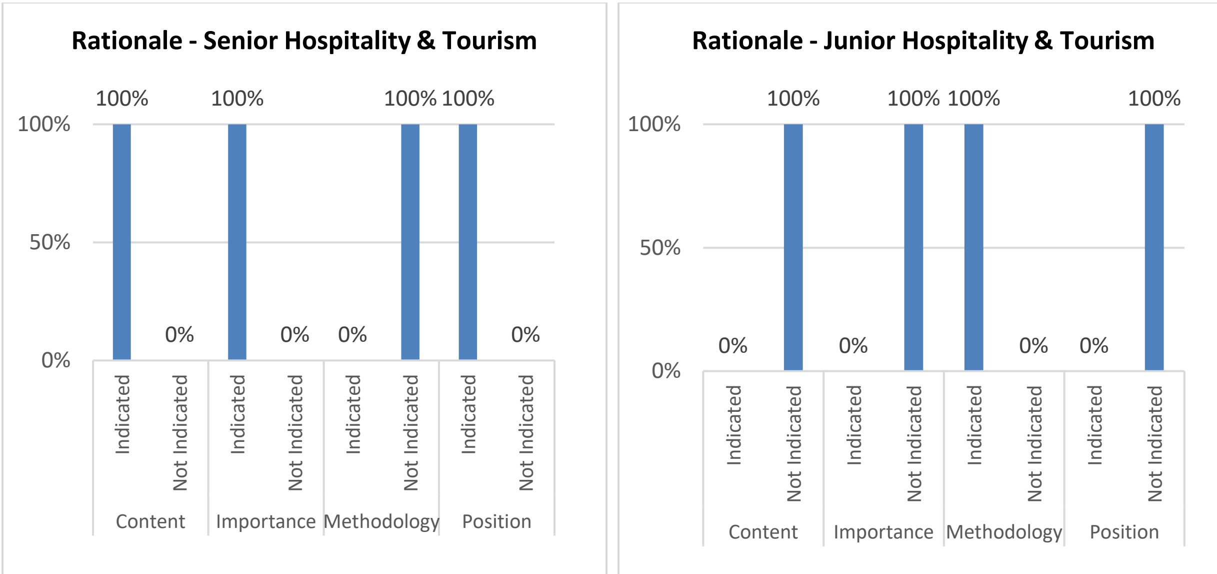


Figure 61: Rationale - Senior and Junior Hospitality & Tourism

The Hospitality and Tourism 2019 STEM Transitional Curriculum proposes Inquiry Discovery, Problem Based Learning, Masterly Learning, Research Approach, 5Es Approach, Subjective Learning, Experimental and Field Work as teaching methodologies to be used in STEM Education learning. However, only Inquiry Based Approach was planned to be used in the lessons.

The disparity in rationale aspects at junior and senior levels indicates varied understanding of what should constitute a rationale. At junior level the indication of only the methodology aspect might suggest that the understanding of the rationale was highly compromised and skewed towards one aspect. However, the indication of the content, importance and position aspects at senior level entails that there was understanding of what to teach, why and when it should be taught and learnt. The implication of having the content and importance is that, on one hand, learner needs would be addressed and on the other hand the significance of learning a particular concept could be taken into consideration. Nonetheless, the aspects indicated did not contain adequate information as seen in the case below.

> "*The lesson will help the learners to understand the sources and functions of food. The learners will acquire skills in understanding the sources of food*"

It can be seen that the knowledge and content aspect in the rationale were not satisfactorily attended to. The STEM Hospitality & Tourism curriculum provides learners with opportunities to explore inter-relationships with other disciplines and also prepare learners for the 21st Century socio-economic environment. To do so rationales developed should have substantiation on not only how the knowledge would be applied in everyday life but indication of the expected skills to be realized in the learning process too. Therefore, the content part of what is to be taught and learnt should also be explicit in the rationale. In order to improve lesson planning in terms of rationale development, there is need therefore, to enhance professional development activities in the Hospitality and Tourism.

The teaching and learning method planned to be used out of all the methods suggested in the curriculum was inquiry. Planning to use inquiry method meant that teachers understood the relevance of using methods that would engage learners into deeper understanding of concepts. The implication is that from this understanding of methods to use in STEM Education, lessons would be planned in such a way that the learning would progress from curiosity into critical thinking and deeper levels of understanding Hospitality & Tourism concepts. Inquiry helps learners to investigate using structured, guided, open or confirmatory activities. Therefore, whilst inquiry was planned to be used, specifying which type of inquiry will be utilized should be explicit to help plan for the lesson activities effectively.

g) Mathematics

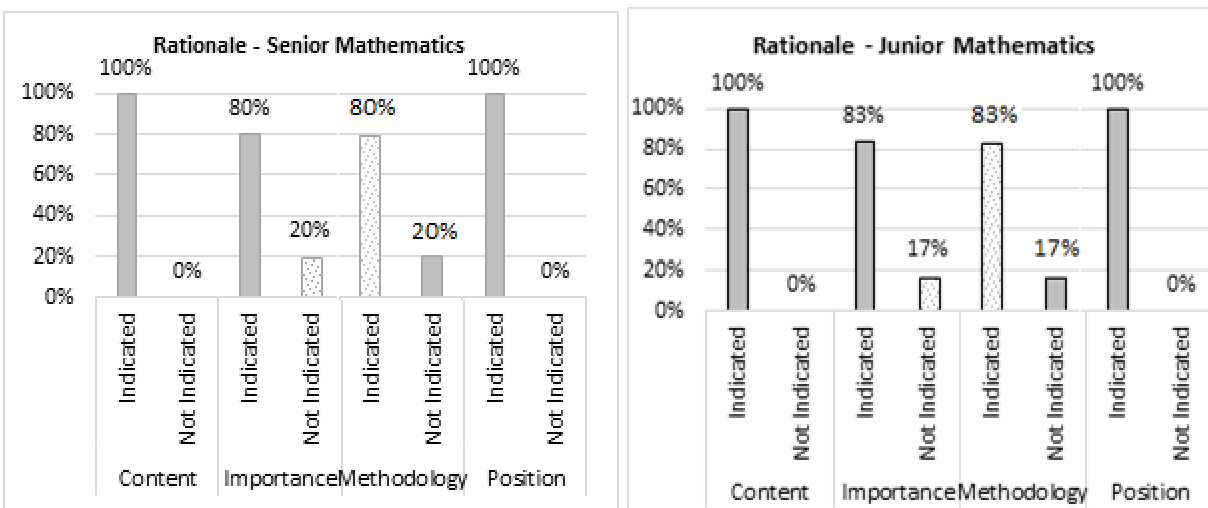


Figure 62: Rationale for Senior and Junior Mathematics

Figure 62 shows the aspects relating to rationale in Mathematics lesson plans at both senior and junior levels. The findings revealed that there was remarkable indication of all the aspects at both levels.

Table 15 indicates the methodologies stated on the rationales of the Mathematics lesson plans observed and those suggested in the STEM Education Curriculum.

Table 15 Methodologies indicated in Mathematics Lessons

Methodology	
Indicated on Lesson Plan Rationale	**Suggested in the curriculum**
Guided inquiry, Investigation, Discussion, Problem-solving, Group work, Discovery, Cooperative learning, Demonstration	Problem Solving, Project, Discovery, Cooperative and Heuristic Methods.

The Mathematics findings in terms of the rationale indicated remarkable results as all the lesson plans at junior and senior levels had rationale aspects planned for and indicated on the lesson plans. This attempt to indicate the outline of what was to be taught and when as well as the relevance of the lesson to everyday life on the lesson plans during the planning stage could entail that teachers understood the curriculum knowledge and value aspects as they were able to plan for them. Likewise, many everyday life activities such as trading, involve mathematical aspects of counting, estimation, measuring, working out formulae and using statistics amongst others. Therefore, if the importance aspect of the rationale is effectively implemented then ultimately learners will apply the mathematical concepts in their everyday life and be in position to solve problems affecting modern day society. However, despite the importance being indicated on the lesson plans the information was not adequate. Three cases in point were that of fractions which had the following as value aspects of the rationale:

> Case 1: "…*fractions are important because they tell you what portion of a whole you need. They are used in baking to tell you how much ingredients to use, they are used in telling time as each minute is a fraction of an hour. We use decimals in everyday life while dealing with money, weight, and length…"*
>
> Case 2: "…*the concept of fractions is used in future Mathematics courses and also in many real-life situations e.g baking, telling time, automotive work and athletics*…"
>
> Case 3: "…*the concept of adding and subtracting fractions is used in cookery, business and in farming*…"

From the three lesson rationales on fractions, it was evident that only the usefulness of learning fractions in everyday life was captured in the rationale but the worth was not adequately explained. There are also some misconceptions within the rationale which could be transmitted onto the learners. Issues like telling time as an aspect of fraction may be misleading on the part of the learners. This implies that there was disparity in teachers understanding of why learners should learn the concept of fractions. The importance of learning a concept should bring about standard in behaviour of one's judgement concerning what is important in life. Therefore, importance of teaching fractions should have incorporated the fact that from fractions; fairness in sharing food & workload, precision & accuracy in medicine prescriptions, carpentry, sewing and cooking will be exhibited.

The STEM Mathematics syllabi promote the use of problem solving, project, discovery, cooperative and heuristic methods. From the lesson plans, it is evident that discussion was the most prevalent teaching method which is not necessarily a method in itself but a strategy found in any of the above methods. This could have been so because STEM advocates for communicative skills as one of the essential skills needed by learners in this 21st Century and discussion is one strategy that could enhance communicative skills. Therefore, there is need to explore the methods stipulated in the Curriculum in order to choose the most suitable.

h) Physics

Figure 63 shows the findings in Physics with respect to the rationale indicated on the lesson plans. The results show that all the rationale aspects were considered and indicated on the lesson plans. As regards to the junior level all the aspects were average and above average as shown in the Figure.

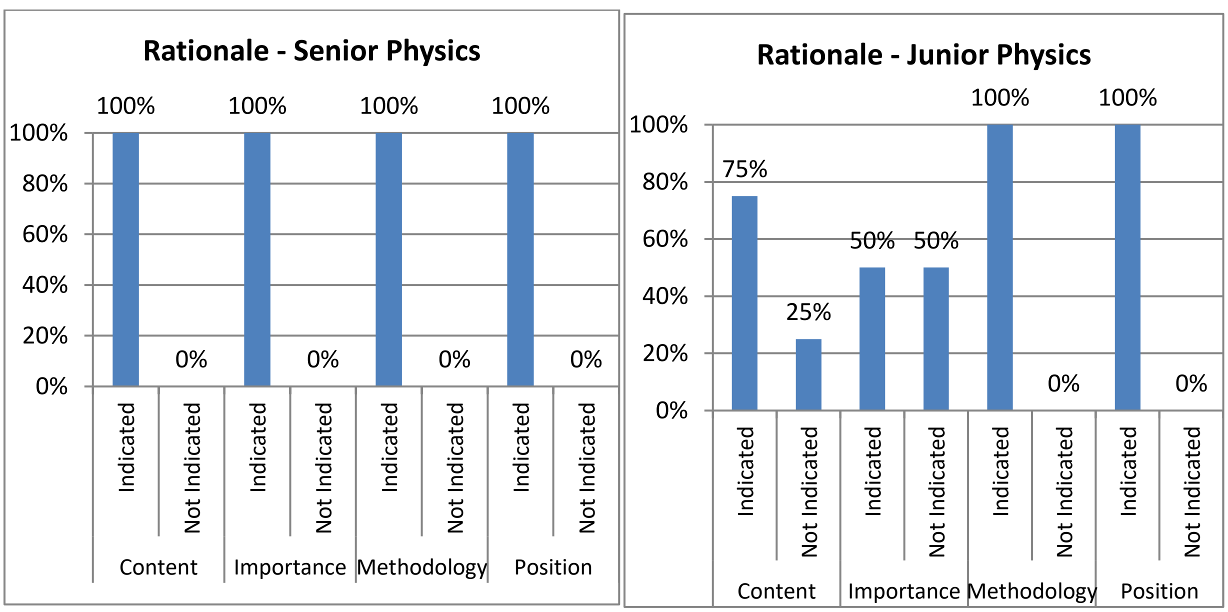


Figure 63: Rationale for Senior and Junior Physics

The methodologies indicated on both junior and senior Physics lesson plan rationales were as shown in Table 16.

Table 16: Methodologies indicated in Physics Lessons

Methodologies Indicated on Lesson Plan Rationale	Suggested in the curriculum
Inquiry, Group Work, Discovery, Discussion, Research, Experimentation,	Inquiry Discovery, Problem Based Learning, Masterly Learning, Research Approach, 5Es Approach, Subjective Learning, Experimental Model Building and Field Work

The Indication on lesson plan rationales of what was to be taught, when it would be taught and learnt as well as the relevance of the lesson concept to everyday life during the planning stage could entail that there was understanding of curriculum knowledge and value aspects. Physics is an important aspect of STEM as it governs everyday life. Therefore, it is essential that the rationale aspects in Physics elaborate how the understanding of Physics content would be connected to everyday activities as well as help to solve the challenges that characterize contemporary society. Nonetheless, despite the importance aspect of the rationale being indicated on the Physics lesson plans the information was not adequate. Cases in point amongst others were:

> Case 1: "*This lesson will help learners understand the significance of length in our world today. The learners discuss the importance of Physics. The approach will be…"*

The rationale not only had insufficient content and importance but also lacked information on the skills that were expected to be acquired in the learning process and how they would be applicable and useful in everyday activities. The reason of not including adequate content in the rationale could be due to deficiency in understanding of curriculum intentions and so it was difficult to plan for the content and significance of the lessons. A case that showed that there could have been inadequate understanding of curriculum intentions as well as rationale lesson aspects is shown below:

> Case 2: "*This lesson is about physical quantities. It is important to the learner because the measurement of physical quantities plays a vital role in standardization of everyday processes. Additionally, it helps to remove the confusion that may arise without understanding length, mass, time, weight, pressure, volume and density. The knowledge of physical quantities will help in making proper estimations when cooking, avoiding wastage by getting rightful food quantities, avoiding*

encroachment by respecting land boundaries as well as avoiding overloading in transportation and exhibiting fairness in trade".

In as much as it is a good value aspect, the content and skill aspects were not included simply because the value was copied word for word from the syllabus. To be meaningful, value aspects of a rationale should be contextual and relate to the local environment and the knowledge of the recipients. Therefore, by direct copying of the value it meant that there was lack of understanding of rationale requirements. The implication of the planned lesson rationales not having the content aspect would lead to misinformation, information overload or information deficiency. This ultimately would impede the provision of knowledge that can help develop desired proficiencies in learners. For a lesson to be well planned, a teacher needs to have adequate understanding of curriculum content knowledge of the subject matter for them to effectively plan what and how the information will be learnt. There is need, therefore, to capacity build teachers in construction of rationales in order to enhance their planning skills.

Furthermore, the methods aspects of the rationale were remarkably indicated in Physics lesson plans at both junior and senior levels. It is essential for Physics STEM lesson rationales to have the method aspect. This is because methods give an indication of how particular concepts would be learnt. Since the methods were indicated on Physics lesson rationales developed during planning it entails that there was considerable understanding of curriculum intentions in terms of the teaching and learning approaches to use. The methods listed in Physics lessons were all in line with suggested curriculum methods. These methods are recommended as they facilitate the incorporation of activities that enhance modern day society attributes such as interaction, collaboration & teamwork amongst others. All in all, a good lesson rationale should have the content, concept, methods and location as exemplified in the Reference Material for Teachers and Teacher Educators: Integrated Science Grade 5 (MoGE, 2019) which stated a rationale on lesson topic volume of irregular solids as:

"*Each object occupies its own amount of space or each container can hold a certain amount of liquid. The amount of space occupied by a substance is measured as its volume. The bigger the size of the object the bigger the volume it has and vice-versa. Volume of a regular solid can be found by measuring its dimensions (length, breadth and height) and then using formulae to calculate the actual volume. Volume of irregular solids be found by measuring the amount of liquid displaced by the object. In this lesson learners will design and conduct an experiment to determine the volume of irregularly shaped solids by displacement of liquid through problem solving approach and group work. Through designing and conducting the experiment, learners will be expected to enhance their creativity and investigative skills as well as understanding of the concept of volume and its measurement. Since volume is a fundamental property of matter which will be used through-out science and in everyday life, this will help learners to study a lot of* *related topics in science as well as be aware of and take into account the measurement of different sizes or amounts of substances in their daily life experiences at home when cooking and in the market places when shopping and selling. This is a fourth lesson in a series of four under the subtopic volume."*

In the above rationale the outline of what is to be learnt, why it should be learnt including the application and use of science phenomena to everyday life, how to learn through the provided approaches and strategies as well as the location of the lesson were elaborate. To be able to plan for such rationales, there is need to strengthen CPD activities at all levels that engage teachers in intensive study of teaching and learning materials.

Planning for Lesson Rationale Summary

Figure 64 shows aspects relating to rationale across all the STEM subjects. The findings reveal that there was above average indication of all aspects across all subjects except for methodology (31%) which was below average.

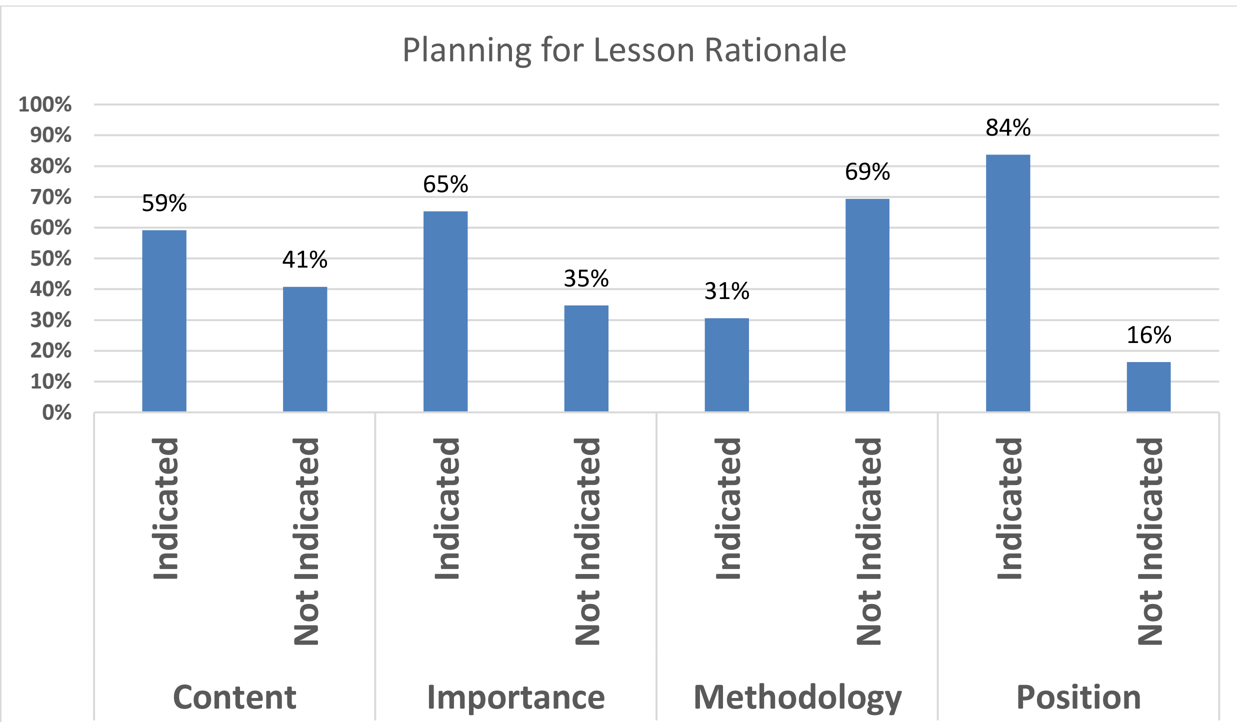


Figure 64: Summary of Planning for Lesson Rationale

The above average indication of content, importance and position aspects of the rationale across all the STEM subjects means that some teachers had proficiencies that helped them to construct lesson rationales. This suggests that there were efforts in planning for what was to be taught and learnt, when it was to be taught and its relevance in life. However, despite having indication of these aspects there was insufficient depth of content information and relevance provided. This could mean that in as much as teachers were able to indicate the rationale aspects, they were not very much grounded in how elaborate the aspects should be.

The below average plans of methodology aspects raise a lot of concern as it meant that teachers were not able to plan on how the lesson concepts were to be learnt. Additionally, discussion which is not primarily a method in principle was the most prevalent teaching method planned to be used across all the STEM subjects. The implication of this is that, teaching and learning activities would not be well organized in preference to STEM learning requisites. An explicit and detailed rationale is an indication that a teacher has understood the curriculum intentions. Therefore, in order to meet curriculum demands, development of well thought out rationales should be part of the lesson planning process.

4.1.4.3. Planning for Lesson Introduction

Lesson introduction provides interest and motivation to the learners by focusing learner's attention to the purpose of the lesson. Planning for lesson introduction is essential because it helps to have an organised set of activities that could guide the learning process. In order to engage and stimulate learners' interest as well as provoke their thinking it is important to develop creative lesson introductions. There are varied lesson starter activities that can be used during lesson introduction ranging from linking learners to previous knowledge learnt to mind-capturing activities. In the context of this research the planning for lesson introduction will focus on a key task which might include the following; scenarios, key questions or problem statements.

A scenario as an introductory starter activity is a description of events which should have an essential question that learners should address whilst working through it. The role of a teacher is to help the learner to learn and therefore creation of scenarios as lesson introduction starter activities is imperative. Lesson scenarios allow learners to explore concepts in depth and depending on its focus it could also help in the development of scientific skills. Key questions drive the learning process. They direct the content and process to ensure effective teaching and learning. Planning to use Key questions in lesson introduction helps to organise content and direct instructional choices. Key questions should, therefore, be comprehensive and well- crafted in order to give direction and purpose of learning. A problem statement is a thought-provoking statement that should cause exploration of lesson content to move learners towards greater understanding of concepts. The findings and analyses of planned lesson introduction activities across subjects and grades focused on whether the scenario, key questions, or problem statements where planned to be used as lesson starter activities. Further, there was also focus on whether the lesson starter activities were able to foster hypothesizing. The results and analysis are according to the subjects observed as indicated below:

a) *Agricultural Science*

Figure 65 shows the Agricultural Science lesson introduction activity results for both senior and junior levels. The findings reveal that 50% of the senior lessons had problem statements as planned starter activities whilst the other 50 % had ordinary questions. The senior lesson starter activities had average prospects for hypothesising. At junior level all the lessons had ordinary questions (100%) planned as starter activities with no prospect for hypothesizing.

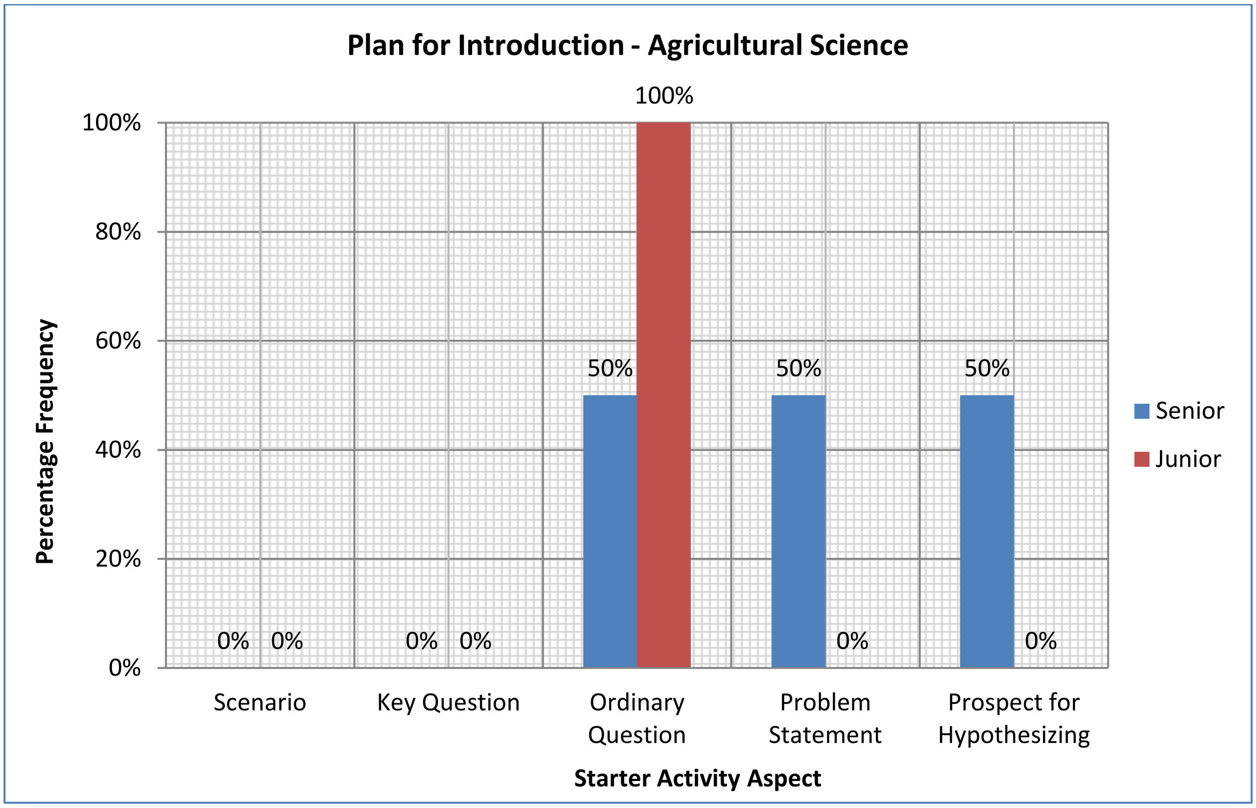


Figure 65: Plan for Introduction for Agricultural Science – Senior and Junior levels

The Agricultural Science results as regards to introductory activities for both senior and junior levels indicated that most of the lessons starter activities planned did not involve the recommended key task(s). Instead, the traditional question posing approach was prevalent. This meant that the starter activities planned for would fall short in soliciting for effective engagement and exploration. The reason for this could have been that there was inadequate knowledge as to what the introduction of lessons should comprise. Another reason could have been lack of sufficient knowledge on how to craft a key question, scenario or problem statement. A case in point showing a planned key lesson task on the topic: Scientific Skills was;

> *"Research shows that the flow of activities between a learner and a teacher has a gap. What do you think could be the cause? How best as an Agricultural student do you think you can help bridge the gap"?*

The task despite having an aspect that could allow for hypothesizing, its intention was not clear and it was difficult to categorize it as a scenario, key question or problem statement. Further, such a task can produce varied responses that would make it hard to progress to the next lesson stage. Not planning for key lesson tasks may imply unfocused lesson activities hence not fulfilling the intentions of STEM Agricultural Science Curriculum. Therefore, good key tasks should be planned for to help postulate a context within which to hold discrete knowledge and skills by unpacking the compelling 'why' part of the lesson. In STEM learning the use of 'why', 'how' and 'to what extent' questions cannot be understated. They should be treated as essential constitutes of lesson introduction because they will help to engage learners' interests in the lesson at the beginning and also throughout the entire lesson.

b) Biology

The Biology results as regards to planned lesson starter activities are shown in Figure 66. The findings reveal that there was above average use of ordinary questions at both senior and junior levels as indicated by 67% and 50% respectively. Meanwhile there was below average use of key questions (33%) and scenarios (33%), with no case in which a problem statement was used. At junior level 50% of key questions were planned for as starter activities.

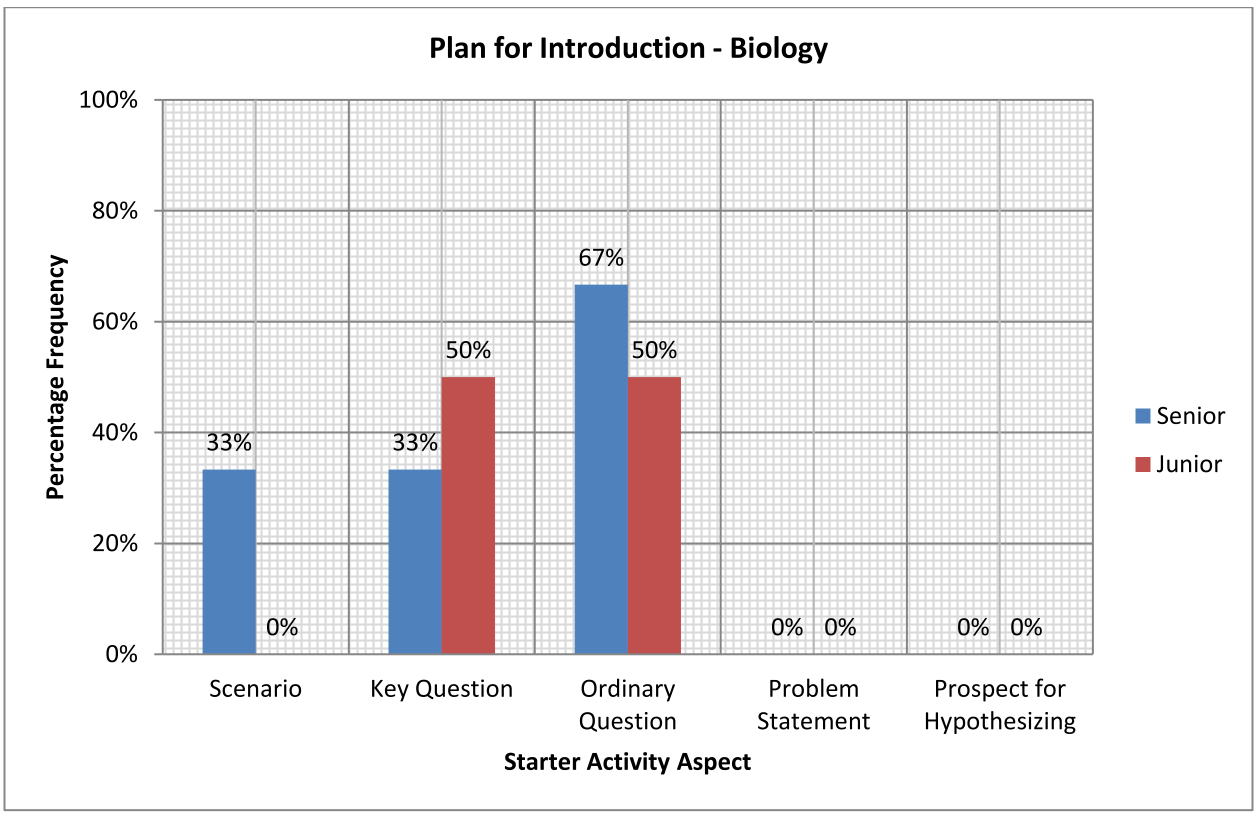


Figure 66: Plan for Introduction for Biology - Senior and junior levels

The Biology results as regards to introductory activities for both senior and junior levels indicated that most starter activities planned did not involve the recommended key tasks. Instead, the customary ordinary question posing was predominant. Also, all the starter activities in the Biology lessons did not have forecasts for hypothesizing. This meant that the starter activities planned for would fall short in beseeching effective engagement and exploration. The reason for this could be that there was no understanding as to what the introduction of lessons should comprise. Other than that, another reason could be that of not knowing how to write a key question, scenario or problem statement on the part of the teacher. A case in point is a scenario developed on the topic apparatus and equipment. The starter activity planned for read as follows:

> *"A girl collapsed during school assembly. She was quickly rushed to the hospital for diagnosis. After her blood sample was examined in the laboratory, the doctor advised her to take lot of fluids and fruits. No sooner had she arrived home than she was given bananas to eat. Design and carry out an experiment to determine the content of the banana that would make her adhere to the doctor's instructions of eating fruits"*

The scenario does not indicate a focus on apparatus and equipment rather it was centred on the nutritional composition of the fruit. This showed that there was lack of knowing how to write a starter activity. Other than that, it also did not project for hypothesis to be provided. Hypothesizing is important because it helps to come up with a list of possible solutions and work out pragmatic solutions about a concept. This is one amongst the many other ways learner's knowledge and abilities to be innovative can be cultivated. Consequently, planned starter activities not having the prospect of hypothesizing implied there would be no activation of desired STEM learning outcomes in the learning process. Therefore, a good key question should help provide a basis within which to hold distinct content knowledge and skills through the 'why' part of the lesson. In STEM learning, the 'why', 'how' and 'to what extent' questions cannot be over-accentuated as essential in planning for lesson introduction because they will not only help develop learners' interests at the beginning but also throughout the course of the lesson.

c) Chemistry

Figure 67 shows the Chemistry results as regards to introductory activities for both senior and junior levels. The findings disclose that almost all the planned Chemistry introductory activities involved the use of ordinary questions except for one attempt on problem statement. Additionally, no lessons had starter activities with prospects for learners to hypothesize the possible solutions.

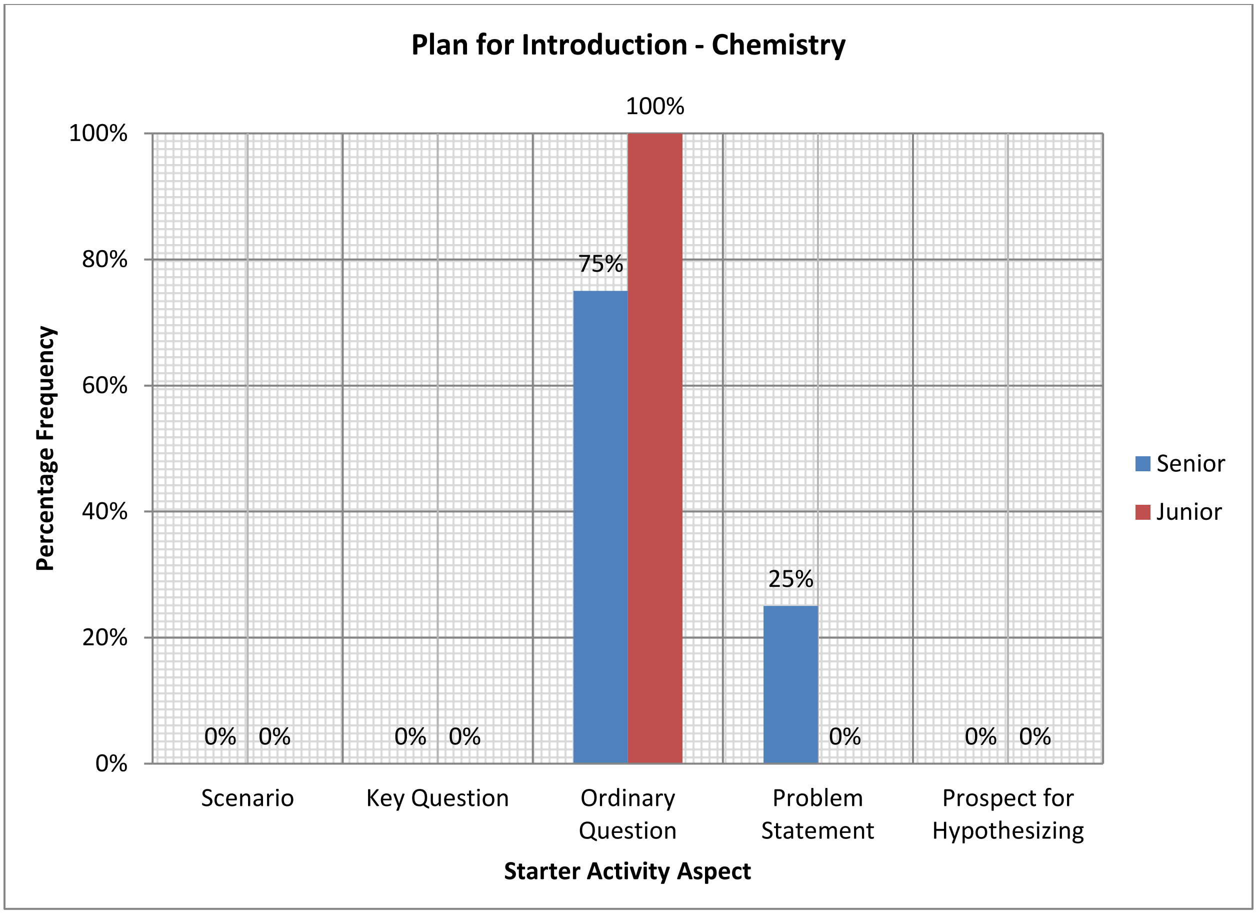


Figure 67: Plan for Introduction for Chemistry - Senior and junior levels

The Chemistry results as regards to introductory activities for both senior and junior levels indicated that none of the lesson starter activities planned involved the recommended activities of key question, scenario or problem statement. Instead, the conventional ordinary question posing style was predominant. It is apparent that teachers were still dwelling in the positivist approaches resulting in starter activities not having conjectures for hypothesizing. The reason for this could be that the teachers did not know that they needed to plan for introductory lesson activities. Additionally, they could not distinguish between an ordinary question and a key question. The attempted problem statement is as shown in the illustration below:

> "*You have been provided with water collected from one of the garden taps of... STEM school, investigate the ions present in this, basing on this fact*"

The statement above though classified as a problem statement does not contain all the key elements. In a problem statement the problem should be well stated, there should be at least one of the 5Ws (who, what, why, where or when) and the problem should be solvable.

Computer Science

The Computer Science results as regards to introductory activities for both senior and junior levels are shown in Figure 68. The findings indicated that there was above average plans to use scenarios as key task activities at both senior (60%) and junior (50%). However, the aspects of key question and problem statement were lowly indicated on the lesson plans as starter activities. The general question and answer activities were observed on 50% of the lesson plans at junior level and 20% at senior level. There was no trace of problem statements on the starter activities and the key tasks did not contain prospects for hypothesizing solutions.

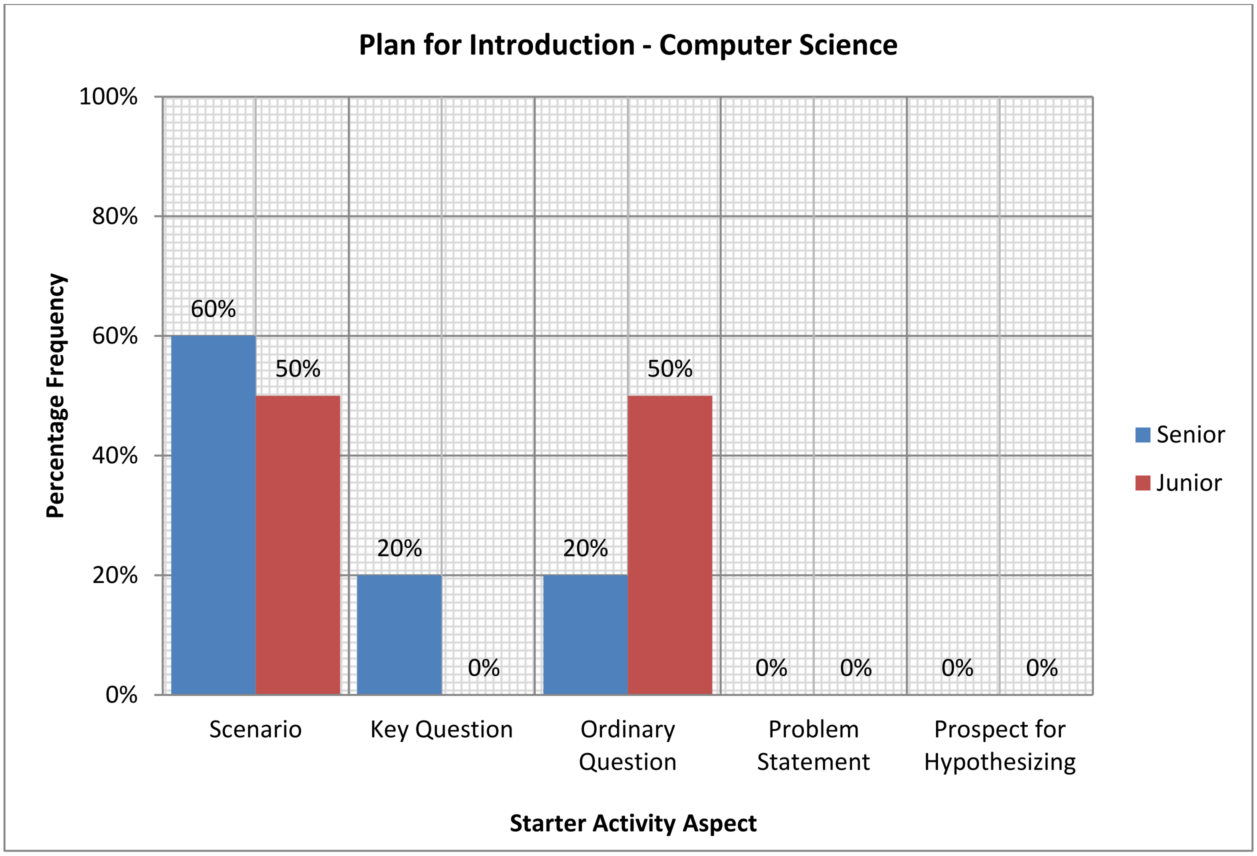


Figure 68: Plan for Introduction – Computer Science

The computer science lessons showed planning for scenarios at both senior and junior levels and to a lesser extent key questions (at senior level) as introductory activities. The indication of these starter activities entails an understanding of curriculum intentions because the mere plan to use a key question and scenario is a positive step towards achieving desired STEM learning outcomes. However, despite the lesson scenarios and key questions being indicated they lacked hypothesis prospects and questioning techniques that needed to propel desired competencies. This meant that the starter activities planned for fell short of persuasive engagement and exploration. The teachers seem to have difficulties to construct suitable key question, scenario and problem statement to drive the lesson process. A case in point is a scenario developed on the topic Computer Architecture. The starter activity planned for reads as follows:

> *"… STEM school computer laboratory had an installation of computers donated by government. During installation it was discovered that some computers were not successfully powering up. After an assessment it was realized that part of the primary memory was missing. Explain what a primary memory is and state the categories of a primary memory"*

The above planned computer science lesson scenario was not coined in such a way that it could allow for initial ideas to be elicited, thinking, discovering and constructing knowledge but it gave the missing primary memory as the reason why the computers were not powering. Further, the scenario did not set the tone for the lesson process. Therefore, this rendered the activity not forecast in fostering critical and creative thinking. Eliciting initial ideas is important because it helps to come up with a lot of possible and pragmatic solutions about a concept. This ultimately helps in promoting innovative proficiencies. Not having planned starter activities that could enhance hypothesizing implies that there would be no activation of desired STEM learning outcomes in the learning process. Therefore, a good key task will elicit ideas, foster exploration, and channel lesson activities to expand initial ideas as well as explain new ones.

Design and Technology

Figure 69 shows introductory lesson activities that were planned for in Design and Technology at both senior and junior levels. There was average indication (50%) of key lesson tasks at junior level except for the key question which was not indicated. At senior level there was 25% indication of scenarios, 75% ordinary questions and no key questions as starter activities. Additionally, there was no indication of problem statement in any of the lessons planned. The starter activities at both senior and junior levels did not have prospects for hypothesizing planned for.

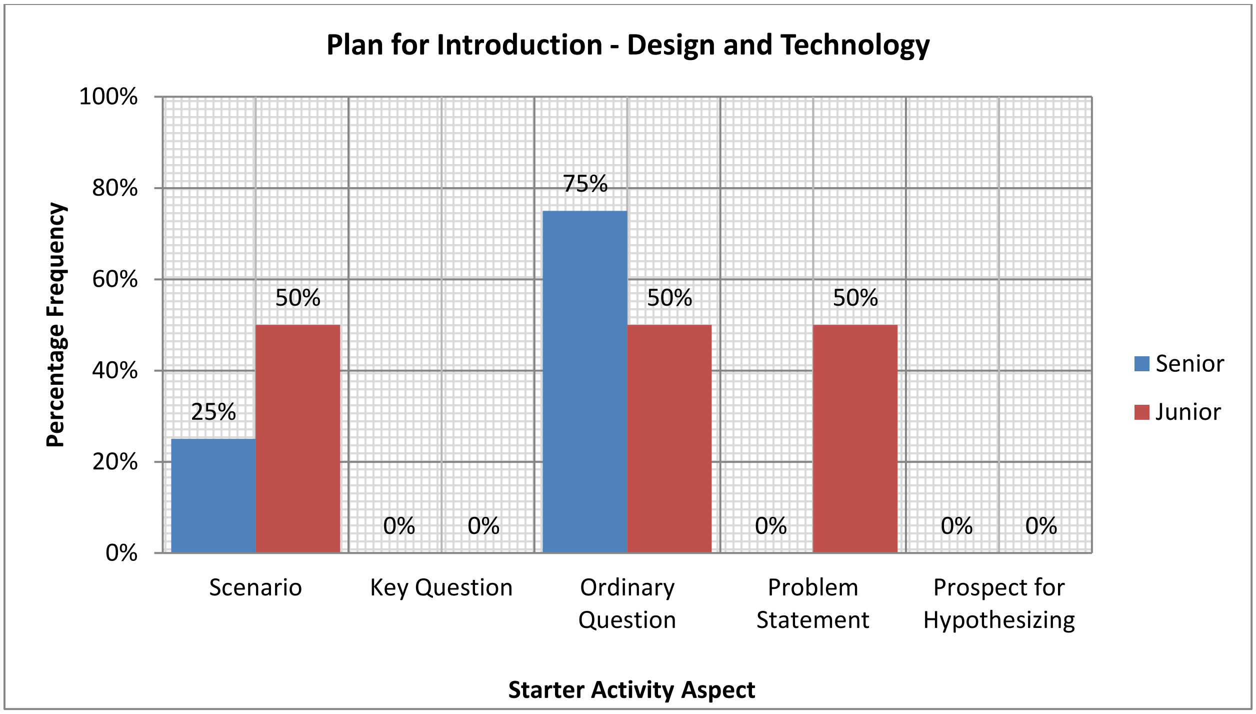


Figure 69: Plan for Introduction for Design and Technology – Senior and junior

The Design and Technology lessons showed insignificant planning involving scenarios and problem statements as introductory activities. Most lessons had ordinary questions planned as introductory activities. On one hand, the mere indication of these starter activities entails an understanding of curriculum intentions because problem statements and scenarios are progressive steps towards achieving desired STEM learning outcomes. On the other hand, the lesson scenarios and problem statements indicated lacked elements of fostering hypothesizing and techniques that needed to propel desired competencies. The reason for this could be lack of skills and competencies for phrasing appropriate key tasks. The following two cases were considered for discussion:

> *Case 1: "A pentagon is a five-sided polygon which can be regular or irregular, teacher asks learners to discuss the difference between a regular and irregular pentagon"*

The above starter activity was very traditional as it places the teacher at the centre of learning. It does not contain elements that would help elicit ideas and foster exploration. The question could have been planned in such a way that it elicited a lot of possible and pragmatic solutions. Thereafter, activities to foster exploration and expansion of ideas would have been more appropriate. The second case was a graphic communication scenario which read:

> *Case 2: "You have just been employed in the architectural department in a new branch of a cement making company here in this town. Being a designer you have*

been asked to come up with a line which should demarcate where to end when constructing on paper and inserting of particulars. How do you present it?"

This was a good scenario as it brought out contextual learning. However, it was guiding at the end and so could not have probability to elicit creativity and innovativeness which are among the key attributes needed to be developed in STEM teaching and learning. Therefore, a good key question needed to be characterized with the 'why', 'how' and 'to what extent' questions because these will not only help develop learners' interest at the beginning but also throughout the course of the lesson.

d) *Hospitality and Tourism*

The Hospitality and Tourism results as regards to lesson introductory activities for both senior and junior levels are shown in Figure 70. The findings indicate that both senior and junior levels there were no plans for any other starter activities except for ordinary questions. And being ordinary the questions planned for could not bring out prospects for hypothesizing as shown.

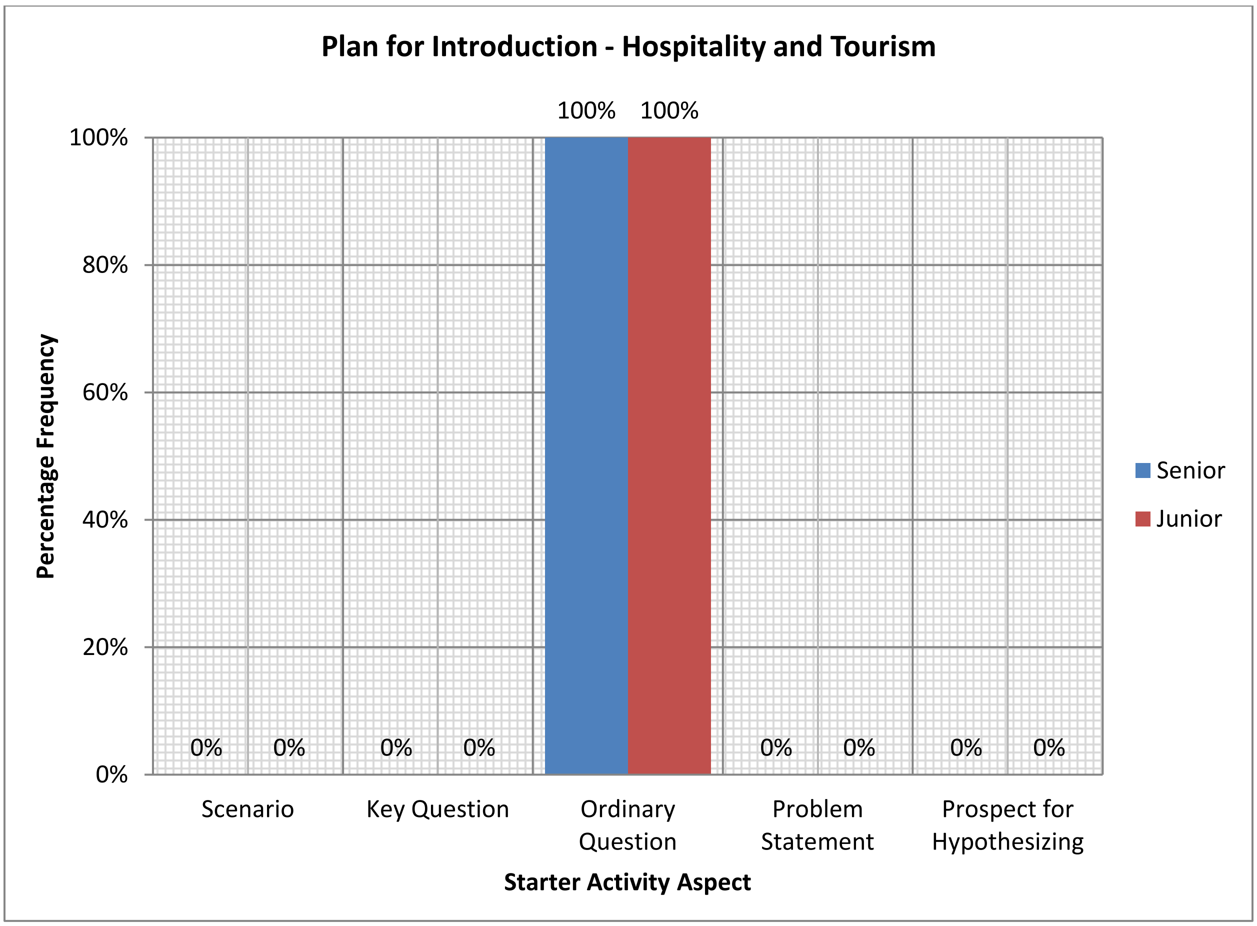


Figure 70: Plan for Introduction for Hospitality and Tourism – Senior and junior

None of the lessons starter activities planned for Hospitality and Tourism involved the recommended activities of key task instead, the conventional ordinary questions were predominant. For instance, a case showing an ordinary question developed as a starter activity on the topic food was;

> *"What are various types of food, what are their functions?"*

The starter activity did not have provision to allow for hypothesizing because the question lacked a statement that could lead into bringing out ideas. Such type of starter activities cannot provoke learners to think deeply beyond the statement provided by the teacher thereby limiting their potentials to analyse critically. The reason for all the lessons having only ordinary questions planned for as introductory lesson activities might be that teachers were still being influenced by teacher-centred approaches. Another reason could be that teachers were not well acquainted with formulation of key lesson tasks.

e) Mathematics

Figure 71 shows results for the planned introductory lesson activities in Mathematics. The findings indicate that the most prevalent was ordinary questions at 80% and 83% for senior and junior levels respectively. Tasks involving key questions, as starter activity at senior level, were 20% and none at junior level. Problem statement was at 17% for junior only. There were no scenarios planned for as lesson starter activities at both senior and junior levels.

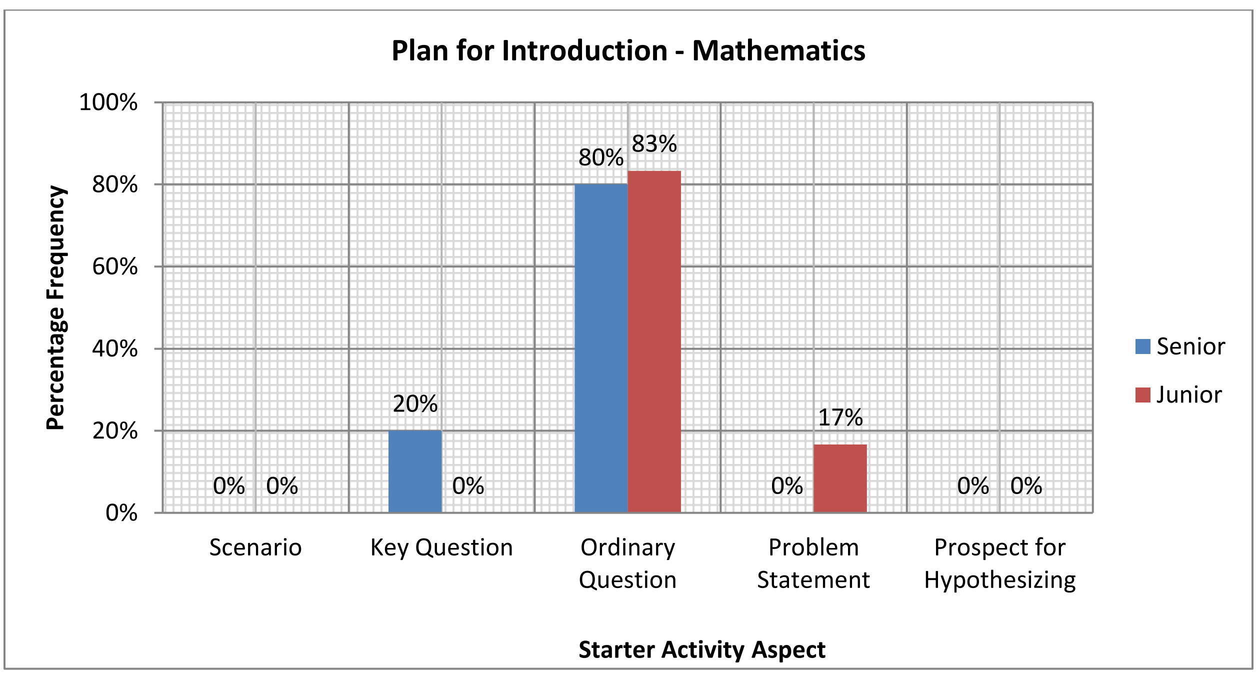


Figure 71: Plan for Introduction for Mathematics – Senior and Junior

The results showed that not only very few Mathematics lessons had planned to use key questions, scenarios or problem statements but also that the starter activities were also not appropriate. This means that the starter activities planned for were not the ones encouraged in STEM teaching and learning. The reason for this could be that there was lack of knowledge as to what should constitute the introduction of a lesson. Other than that, another reason could be lack of adequate knowledge on how to write a key question, scenario or problem statement. The implication of this is that subsequent planned activities would not be focused and hence the intentions of STEM Mathematics Curricula may not be realized when ideas from such lesson plans are implemented. Likewise, none of the Mathematics lesson introductory starter activities had prospects of providing learners with a chance to hypothesize. Cases in point include the introductory activities on the topic of fractions:

> Case 1: stated "*It's your birthday and your mom has ordered pizza for you. When the pizza arrives, you open the box and fine that it is cut into slices. Let's assume that there are 8 slices and you have 7 friends. How much does each person get?*"

The fact that this case was based on a real-life sharing situation was good. However, not all learners may have been familiar with pizza; therefore, contextualization of starter activities is important. Illustrated shapes like squares, circles, rectangles as well as familiar real objects such as sweets, biscuits, gums, amongst others could be appropriate as teaching learning aids to use in the starter activities on fractions. The second case was a lesson introductory activity that had three question aspects namely:

> Case 2: "*Write the fractions in order of size,* $\frac{2}{5}$, $\frac{5}{6}$ *and* $\frac{3}{5}$ *", "find the H.C.F of 8 and 12 and "find the LCM of 3,6,5,4 and 5"*

> Case 3: "*Using a metre rule, measure the length in centimetres of your exercise book and two desks joined together and express your answers as a fraction of a metre rule in centimetres then write the answers in ascending order.*"

The above 2 cases, looked at fractions beyond equal sharing. For these two starter activities plans should have focused on reasoning strategies which should include either area, linear or set models. These models if well planned help in soliciting mental imagery reasoning to make conjectures as well as verifying and discussing solutions.

The three cases above like all other planned Mathematics lesson starter activities had no probability of fostering hypothesizing as the lesson plans further suggested only one expected solution from the starter activities. Hypothesizing is important because it helps to predict possible and testable solutions about a concept or idea. This is one amongst the many other ways learners' knowledge and capacity for innovation can be activated. Consequently, planned starter activities not having the prospect of hypothesizing implied that there would be no activation of desired

STEM learning outcomes in the learning process. Therefore, a good key question should help provide a framework within which to hold discrete knowledge and skills by unpacking the compelling 'why' part of the lesson. In STEM learning the 'why', 'how' and 'to what extent' questions cannot be over-emphasized as essential in planning for lesson introduction because they will not only help engage learners' interest at the beginning but also throughout the entire lesson.

f) Physics

The Physics results for both senior and junior levels on starter activities are shown in Figure 72. It was observed that key question was available at senior level lesson plans while at junior level 50% of the lesson plans indicated key question as the starter activity. The other aspects (problem statement and prospect for hypothesizing) were not indicated on the lesson plans. It was further observed that the scenario was only indicated on 25% of the lesson plans at junior level.

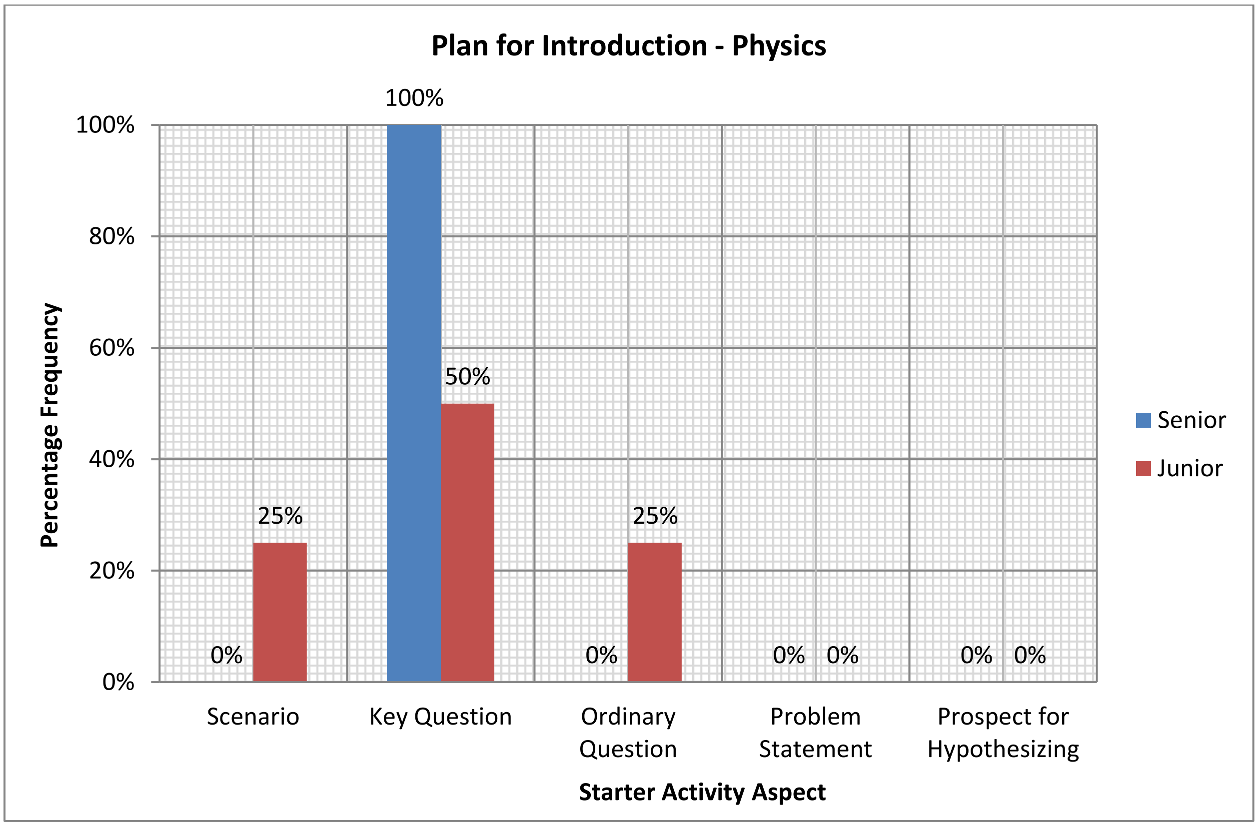


Figure 72: Plan for Introduction in Pyhsics

The Physics lessons showed outstanding planning involving key questions as introductory activities at senior level. The indication of these starter activities signifies an understanding of curriculum intentions and formulation of suitable rationales. This is so because planning to use a key question is a positive step towards achieving desired STEM learning outcomes. However, despite key questions being well developed in the Physics lesson planning process, they lacked the aspects of scenario, problem statement and prospects for hypothesizing that needed to activate desired proficiencies. Therefore, capacity in this aspect is required for teachers of Physics. The following case in point is a key question developed on the concept volume. The starter activity planned for read as follows:

> *"What is volume and how can you calculate it for both regular and irregular solids?"*

The above key question was constructed in such a way that it could neither allow for stimulation of initial ideas nor discovery of knowledge prospects. It is evident that it was portrayed in the positivist way. Furthermore, it is loaded with too many concepts to be exhausted in one lesson. This could be as a result of lack of deep conceptual and pedagogical understanding in key question development and indeed key tasks that stimulate ideas and foster critical, creative and analytical thinking.

Figure 73 shows the summary results indicating the lessons starter activities planned for in all the STEM subjects which were observed. The findings disclose that ordinary questions were more prevalently planned for as introductory lesson activities at both senior (56%) and junior (62%) levels. The recommended lesson introductory activities were largely shunned at both senior and junior levels with scenarios at 19% and 14%, key questions at 15% and 14% and problem statement at 7% and 10% respectively. Prospects for hypothesizing were very low at senior level (4%) while none of the lessons planned for at junior level had indications to that effect.

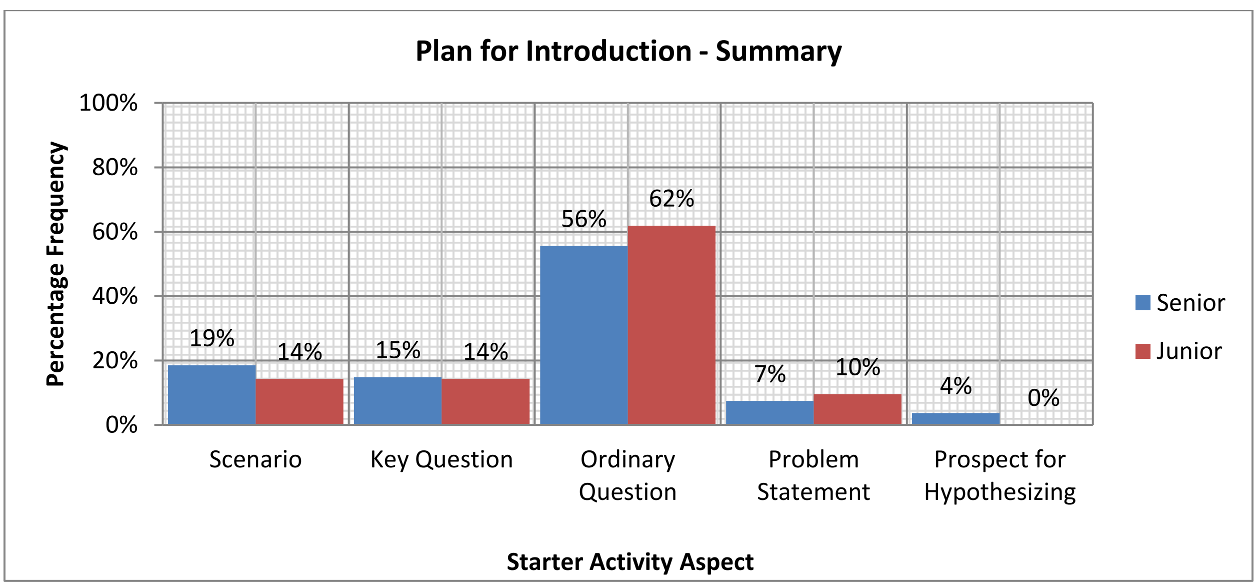


Figure 73: Plan for Introduction for all subjects - Summary

The key tasks are essential in STEM Education as lesson starter activities, either as scenarios, key questions or problem statements, because they tend to draw learners into the required thinking assertiveness as they analyse the thought-provoking assignments. This is vital to the learners as such tasks can help them to become critical thinkers, creative and analytical participants in the learning process. However, the extensive use of ordinary questions by many STEM teachers as lesson introductory activities while neglecting the recommended key tasks may not accord learners the opportunities to develop the capabilities and competencies as desired in the STEM Education. The inadequate use of recommended key tasks as starter lesson activities by STEM teachers might have arisen from not knowing how to construct them. Another reason might have been the inertia of teachers to shift from positivism to constructivism. This might be influenced by initial teacher training from Universities and Colleges. Additionally, the inappropriately prepared lesson rationales might have affected the way the lesson introductory activities were planned. It is, therefore, recommended that teacher capacity building activities should incorporate how to plan for lesson introductory key tasks formulation.

4.1.4.4. Planning for lesson development

Planning for lesson development is important as it provides a well thought out transition from the introduction into the main lesson. Lesson development outlines the actual flow of the lesson activities that are to take place in the lesson to facilitate teaching and learning as well as to achieve the set lesson outcomes. There are various ways in which lesson activities can be planned for. However, in STEM learning and in this context, the activities planned for in the lessons need to be constructivist oriented. This means that lesson activities need to have the ability to stimulate critical, creative, analytical and innovative thinking. Another aspect of focus under planning for lesson development in this perspective was how the lesson ideas were planned to be consolidated. In the constructivist approach, the learner is allowed and encouraged to construct their own knowledge using what they already know and the immediate environment. The tenets of constructivist lesson flow are that the teacher poses a problem then learners hypothesize, design and present solutions. Finally, the teacher together with the learners, confirm the solutions. Thereafter, more tasks are provided for learners to practice.

a) Agricultural science

The Agricultural Science planning for lesson development results are shown in Figure 74. The findings indicate that the flow of lessons both at senior and junior levels was generally in line with constructivist approach. The lesson plans also showed that lesson consolidation was planned for at 67% for senior level and 100% for junior level.

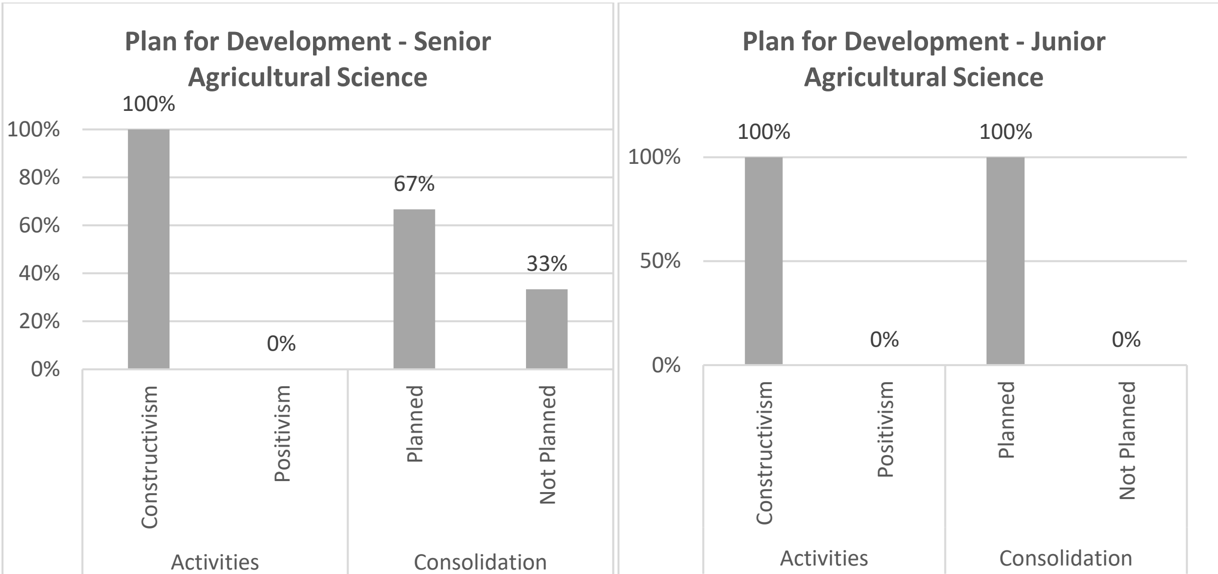
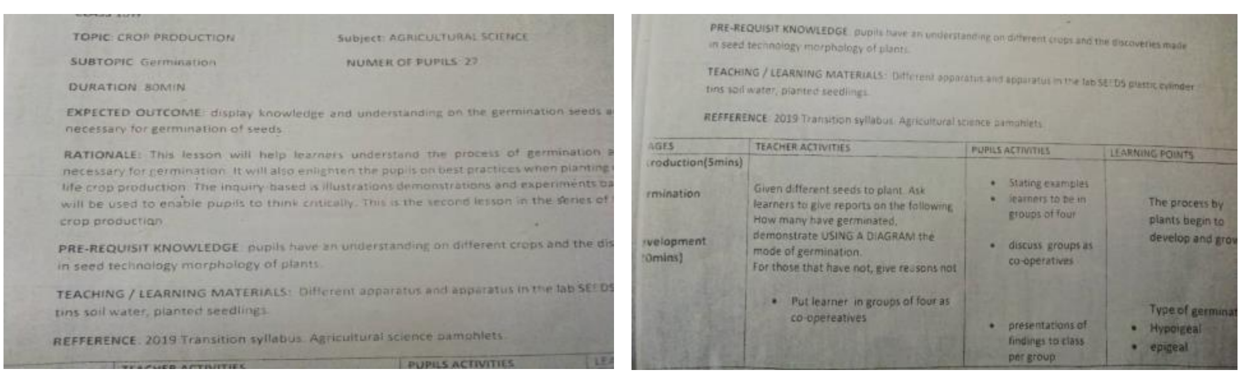


Figure 74: Plan for Development - Senior & Junior Agricultural Science

The Agricultural Science results showed an outstanding constructivist orientation of planned lesson development activities. This could have been as a result of understanding curriculum intentions as regards to the teaching and learning approaches. In the Agricultural Science lesson development activities, there were plans for learners to engage in active thinking and collaboration through discussions. This was a good aspect as it would help in the acquisition of modern-day proficiencies of cooperation and navigating through different ideas. In addition, the planned activities were grounded in authentic real-world context and this had the opportunity to let the subject cultivate curiosity in the learners and relate to real world situations. The implication of this is that some planned lesson activities in Agricultural Science provided opportunities to learn to some extent. However, analysis of the content under lesson development revealed inadequacies in the organization of the teaching and learning activities that would enhance learning outcomes. The case in point is the capture shown in Figure 75:


TOPIC: CROP PRODUCTION Subject: AGRICULTURAL SCIENCE
SUBTOPIC: Germination NUMER OF PUPILS: 22
DURATION: 80MIN
EXPECTED OUTCOME: display knowledge and understanding on the germination seeds a... necessary for germination of seeds
RATIONALE: This lesson will help learners understand the process of germination a... necessary for germination. It will also enlighten the pupils on best practices when planting ... life crop production. The inquiry-based is illustrations demonstrations and experiments ba... will be used to enable pupils to think critically. This is the second lesson in the series of ... crop production
PRE-REQUISIT KNOWLEDGE: pupils have an understanding on different crops and the dis... in seed technology morphology of plants
TEACHING / LEARNING MATERIALS: Different apparatus and apparatus in the lab SEEDS tins soil water, planted seedlings
REFFERENCE: 2019 Transition syllabus. Agricultural science pamphlets

PRE-REQUISIT KNOWLEDGE: pupils have an understanding on different crops and the discoveries made in seed technology morphology of plants.
TEACHING / LEARNING MATERIALS: Different apparatus and apparatus in the lab SEEDS plastic cylinder tins soil water, planted seedlings.
REFFERENCE: 2019 Transition syllabus. Agricultural science pamphlets.

...AGES	TEACHER ACTIVITIES	PUPILS ACTIVITIES	LEARNING POINTS
...roduction(5mins)			
...rmination ...velopment ...0mins)	Given different seeds to plant. Ask learners to give reports on the following How many have germinated, demonstrate USING A DIAGRAM the mode of germination. For those that have not, give reasons not • Put learner in groups of four as co-opereatives	• Stating examples • learners to be in groups of four • discuss groups as co-operatives • presentations of findings to class per group	The process by plants begin to develop and grow... Type of germinat... • Hypogeal • epigeal

Figure 75: Agricultural Science Lesson Plan Samples

In the case of recognizing and validating ideas so that there is readjustment of knowledge and understanding, the junior level showed remarkable indication of planning for lesson consolidation and the senior level showed above average. This could have been as a result of in-depth understanding of curriculum intentions as regards to conceptual and pedagogical aspects. With plans on how different ideas, solutions and explanations would be justified in Agricultural Science implied that alternative conceptions were taken care of and this ultimately resulted into meaningful planning. The few cases that did not plan for consolidation at senior level could be improved by strengthening professional development in the Agricultural Science sections.

b) Biology

The Biology results shown in Figure 76 indicate that as regards to planning for lesson development all the senior lessons translating into 100% and 50% of the junior lessons had lesson development activities planned in a constructivist orientation. As regards to merging of lesson ideas all Biology lessons at senior and junior levels had plans for consolidation.

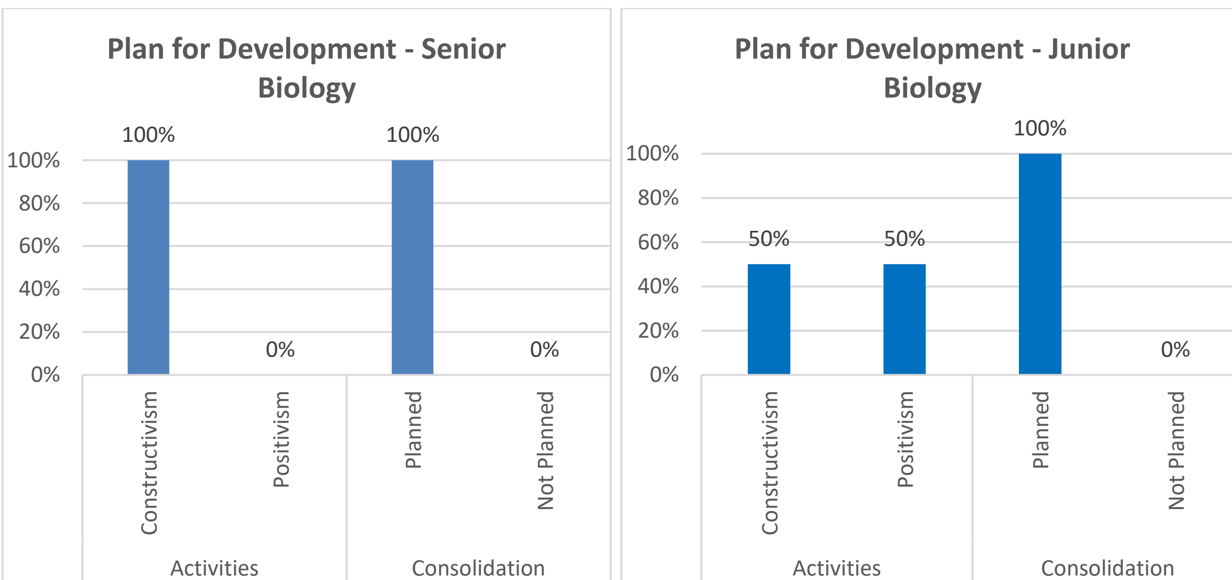


Figure 76: Planning for Lesson Development

The Biology results showed an outstanding (100 %) to average (50 %) constructivist orientation of planned lesson development activities at senior and junior levels respectively. This could have been due to increased understanding of curricula teaching and learning approach intentions by the teacher.

It was found that in the case of Biology lesson development activities, there were plans that had opportunities to foster active thinking and cooperation through discussions. This was a good aspect as it would help in the attainment of modern-day competencies of teamwork and effective communication. One would assume that the planned lesson activities in Biology provided opportunities to learn. Furthermore, in order to acknowledge and confirm viewpoints so that there is modification of knowledge and understanding, Biology showed remarkable indication of planning for lesson consolidation. This could have been as a result of deepened understanding of curriculum intentions as regards to content knowledge and pedagogical aspects. The advantages of having different viewpoints, solutions and explanations justified in the Biology lesson planning process were that misconceptions were taken care of and eventually meaningful planning was done.

c) Chemistry

In the context of planning for lesson development in Chemistry (Figure 77), the results showed that senior lessons had 25% whist the junior lessons had 100 % lesson development activities planned in a constructivist approach. At junior level lesson consolidation was 100 % planned for whilst at senior level it was 75%.

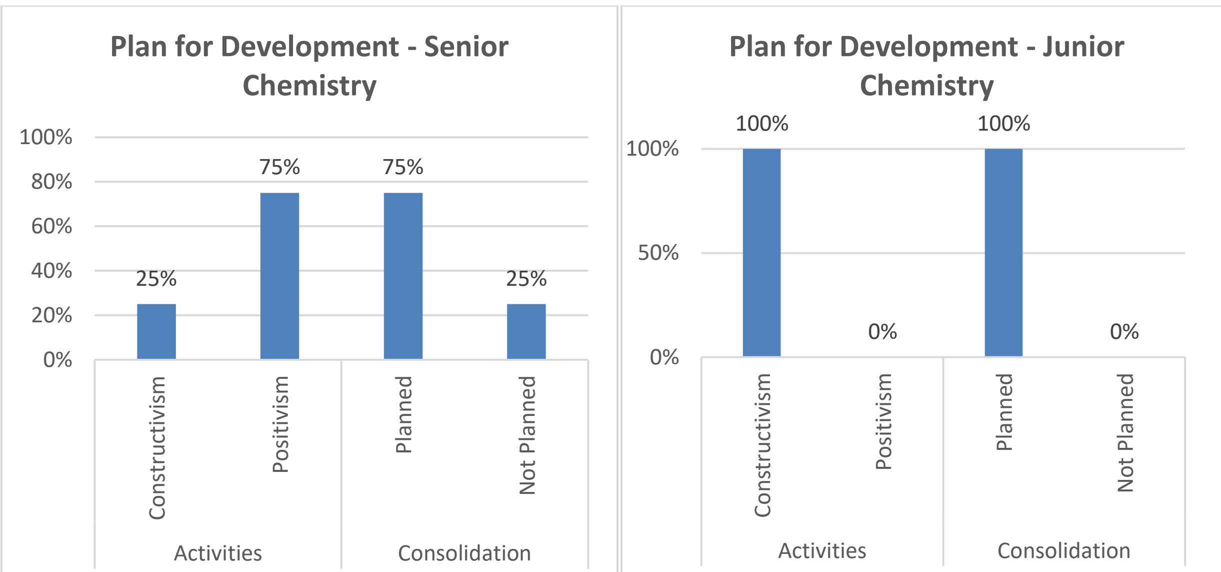


Figure 77: Plan for Development - Senior and Junior Chemistry

The Chemistry results showed both poor and outstanding constructivist orientation lesson development activities planned at senior and junior levels respectively. Therefore, this entailed that, on one hand, there were planned activities that did not have opportunities for fostering critical thinking, creativity and innovativeness, and on the other hand, there were plans that allowed for opportunities to engage and foster active thinking and cooperation through discussions. The reason for this could have been different levels of understanding curriculum intentions in relation to content and pedagogical knowledge. The implication of this is that for some lessons the planned lesson activities in Chemistry provided opportunities to learn whilst in other cases they did not do so. This could ultimately lead to delivery of lessons that would, in some cases and not in others, foster development of proficiencies needed in modern day society. Furthermore, in the case of emphasizing explanations, the junior Chemistry lessons showed remarkable indication of planning for lesson consolidation as opposed to the senior level. This meant that there was deeper understanding of curriculum intentions in terms of the content and effective implementation approaches. The benefit of planning to utilize lesson discussion solutions to emphasize explanations and justify ideas result in taking care of misconceptions and this ultimately lead to meaningful planned lessons. This can be maintained and improved through enhanced professional development activities in Chemistry education.

d) Computer Science

Figure 78 shows the Computer Science results as regards to planning for lesson development at both senior and junior levels. The findings indicate that 60% of the lessons at senior level had the lesson development activities planned for in a constructivist approach and 50% at junior level. Regarding lesson consolidation, senior level was at 80% while junior was at 50%.

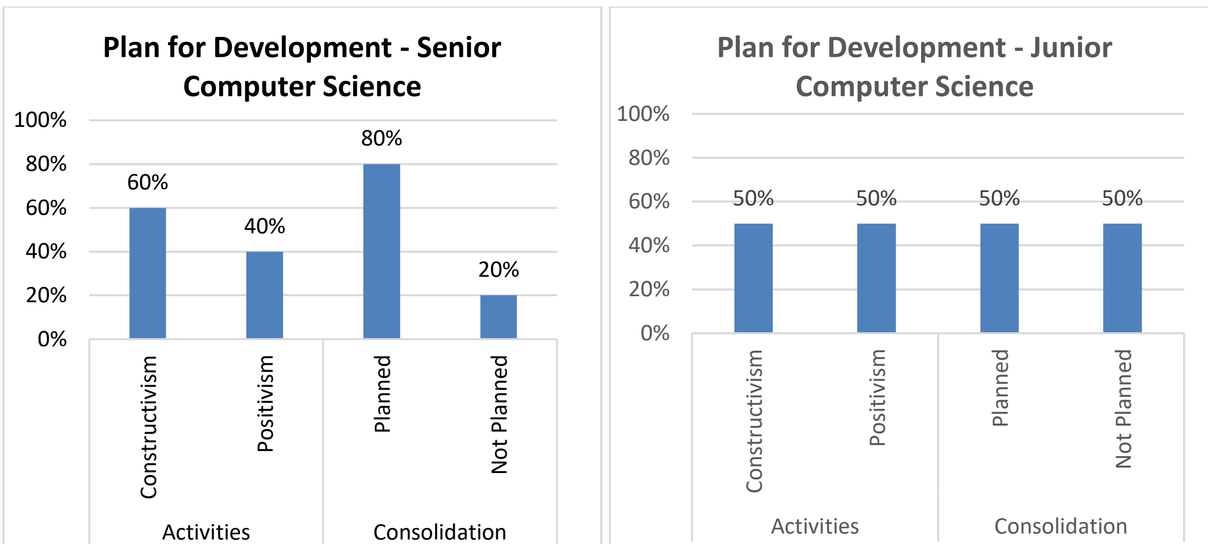


Figure 78: Plan for Development - Senior and Junior Computer Science

The Computer Science results showed that there were on average constructivist focused lesson development activities planned for at both senior and junior levels respectively. Therefore, this entailed that on one hand there were planned activities that did not have prospects for fostering critical thinking, creativity and innovativeness and on the other hand there were plans that allowed for opportunities to engage and promote critical thinking, ingenuity and teamwork through discussions. The reason for this might have different levels of curriculum understanding in relation to content and pedagogical knowledge. The implication of this is that for some lessons the planned lesson activities in Computer Science provided prospects to learn whilst in some cases they did not and this could eventually lead to delivery of lessons that would in some cases and not in others nurture development of competencies needed in modern day society. Furthermore, in the case of emphasizing explanations, the Computer Science lessons at senior level showed remarkable indication of planning for lesson consolidation as opposed to an average at junior level. This meant that in some cases there was some acceptable level of understanding of the curriculum intentions in terms of the content and effective implementation approaches, whilst in other cases this was not the situation. The effect of planning to utilize the learners' ideas during lesson discussion to emphasize explanations and justify ideas leads to taking care of misconceptions and this ultimately culminates into meaningful learning. This can be maintained and improved through enhanced professional development activities in Computer Science education.

e) Design and Technology

The Design and Technology results in Figure 79 show planning for lesson development. The findings indicate that none (0%) of the senior lessons had lesson development activities planned for while at junior level there was 17% effort of planning in a constructivist approach. With regard to planning for lesson consolidation there was 67% and 33% indication at senior and junior levels respectively.

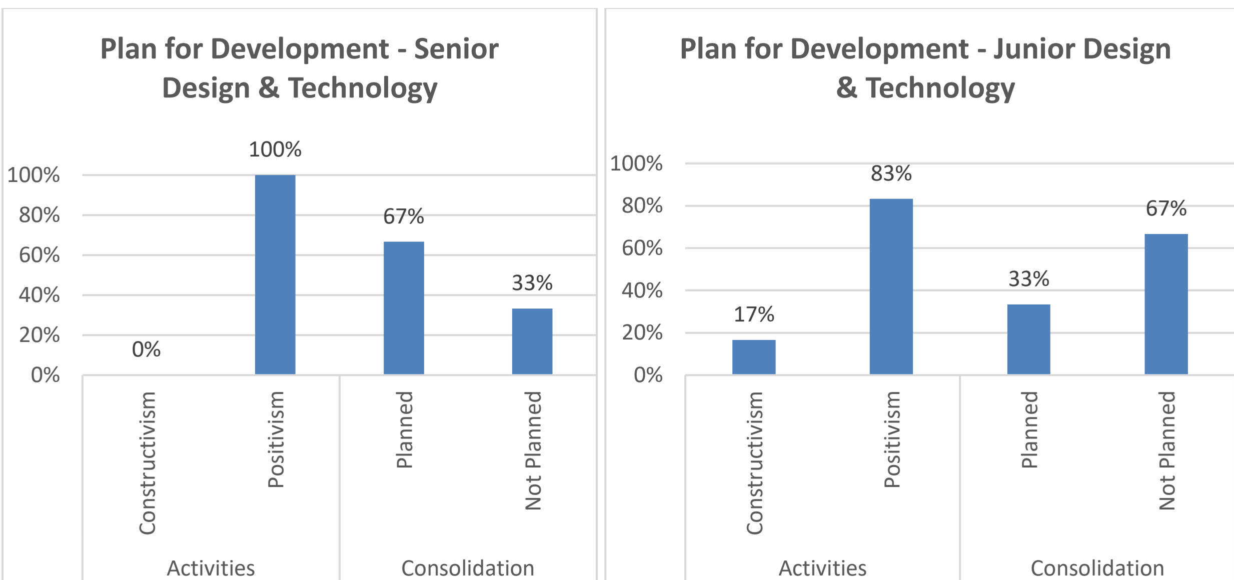


Figure 79: Plan for Development - Senior & Junior Design and Technology

In Design and Technology, results showed very poor constructivist alignment of lesson development activities planned for at both senior and junior levels. This meant that the planned development lesson activities did not have prospects for fostering critical thinking, creativity, innovativeness and collaboration through discussions. There was therefore a struggle to move from positivism to constructivism. The reason for this could have been inadequate understanding of Curriculum intentions in relation to content and pedagogical knowledge. The implication of this was that the planned lesson activities in Design and Technology did not provide opportunities to learn eventually this would result in delivery of lessons that would not support development of the desired skills needed for sustainable development.

Furthermore, in the case of planning for lesson consolidation, the Design and Technology lessons at senior level showed more than average indication compared to the low indication at junior level. This meant that there were, in some instances, a level of understanding of curriculum intentions in terms of content and mode of implementation whilst in other instances this was not the case. The effect of planning to make use of lesson discussion ideas to elucidate and support concepts leads to taking care of conceptions and misconceptions. This may ultimately lead to meaningful planned lessons. This can be maintained and improved through enhanced professional development activities in Design and Technology education.

f) Hospitality and Tourism

Figure 80 shows the Hospitality and Tourism results as regards to planning for lesson development. The results indicate that at senior level the lesson development activities were planned for in a constructivist approach whereas at junior level it was in the positivist approach. With regards to planning for lesson consolidation, the senior lesson plans had total indication while the junior ones had none.

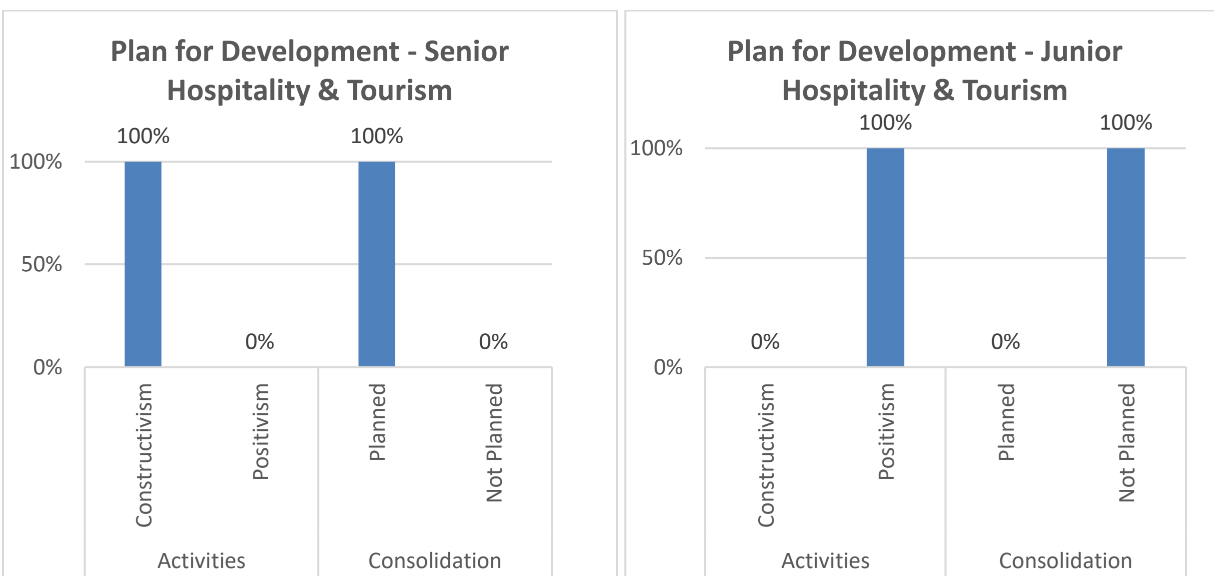


Figure 80: Plan for Development at Senior and Junior levels - Hospitality and Tourism

The Hospitality and Tourism results showed remarkable and poor constructivist inclination of lesson development activities planned for at senior and junior levels respectively. Therefore, this meant that on one hand, there were planned activities that did not have the abilities to foster the expected skills in the learners. On the other hand, there were plans that allowed for opportunities to promote desired learning outcomes. The reason for this might have been variant teacher levels of understanding curriculum purpose in relation to instructional knowledge. The effect of this would be that in some cases the implemented lessons would not lead to acquisition of desired proficiencies. In terms of lesson consolidation, the senior unlike the junior level showed remarkable plans for re-enforcing learner ideas. This might have been as a result of insufficient understanding of curriculum intentions as regards to pedagogical aspects. Plans on how different ideas would be reinforced at senior level imply that apprehensions and misapprehensions would be considered. To bridge the gap between the disparities at senior and junior levels, capacity building activities in Hospitality and Tourism should encompass lesson planning aspects.

g) Mathematics

The Mathematics results regarding planning for lesson development are shown in Figure 81. The findings disclose that the lesson development activities at senior and junior levels were below average and average respectively. In terms of plans for lesson consolidation, the findings indicated above average plans at senior (60 %) level and outstanding plans at junior (100 %) level.

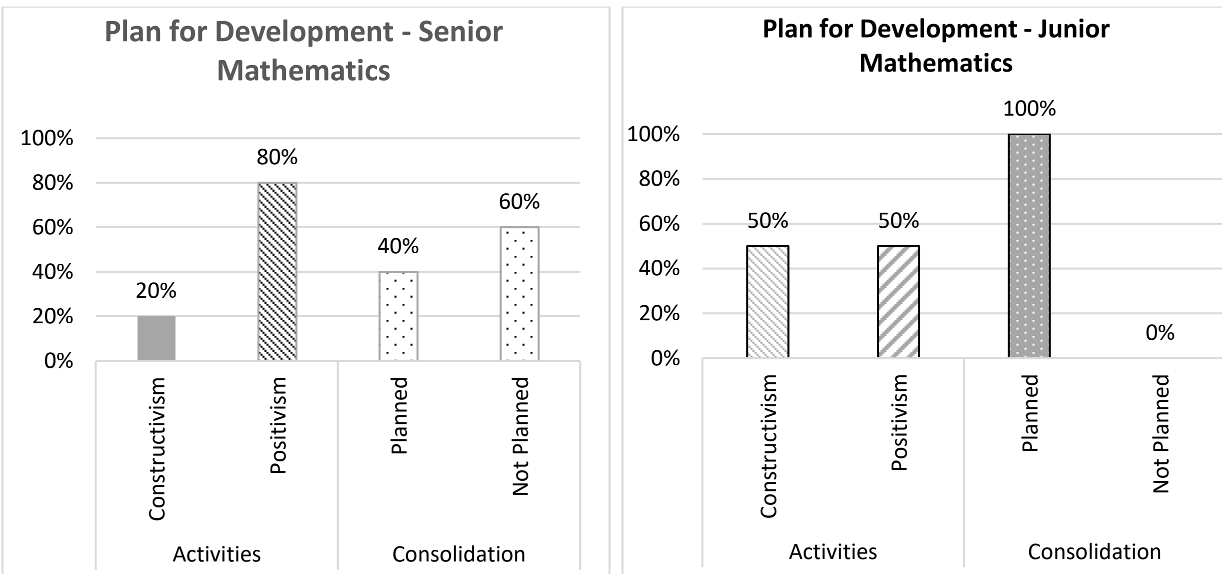


Figure 81: Plan for Development - Senior and Junior Mathematics

As indicated in the results, most Mathematics lesson development activities were inclined towards the positivist as opposed to a constructivist approach. The reason for this might have been insufficient pedagogical competencies by teachers as regards to STEM teaching and learning approaches. This may imply that the planned activities under lesson development did not have prospects to cultivate expected competencies. Examples of lesson development activities are shown in the cases below:

> *Case 1:* Lesson on fractions*: "Arrange the fractions* $\frac{2}{5}, \frac{5}{6}, \frac{7}{12}$ *and* $\frac{3}{4}$ *in ascending order".*
>
> *Case 2:* Lesson on sets*: if A= {Pencil, toothpaste, books, bag, soap, ruler} and B= {Soap, toothpaste, bag, book…}. What is the difference between set A and B?*

In both cases, the planned activities fell short of providing opportunities to stimulate critical, creative or analytical proficiencies. The activities followed the conventional product driven as opposed to being process oriented. This may imply struggles to change from positivism to constructivism way of planning for lessons. However, there were some cases that had analytical tasks with relevance to daily life as shown:

> Case 3: Task on real numbers: "*A scientist specializing in groceries of low temperature investigates the effects of low temperature in bacteria. She cools the bacterium to -47 degrees and another to -87 degrees. What was the difference in the two temperatures?"*
>
> Case 4: Task on Fractions: "*To bake a cake for a particular family, one requires two and half cups of flour. If four and one sixth cups of flour are poured into a bowl. How much flour should be taken out of the bowl?"*
>
> Case 5: Task on Integers*: "A man owes K8000 as a loan. Each of his four children is willing to pay an equal share of his loan. How much will each child pay?"*

Cases 3, 4 and 5 show realigned attempts from rote learning and use of formulae to more contextualized scenarios thereby bringing Mathematics closer to real world situations. In order to be productive as 21st Century citizens both cognitive and practical experiences in Mathematics education are required hence the need to have contextualized learning.

In the case of planned lesson consolidation, the junior level showed remarkable indication of planning for lesson consolidation as opposed to the senior level. The reason for not having planned for lesson consolidation at senior level might have been that teachers misunderstood the notion of learners taking centre stage in the teaching and learning process. Therefore, teachers failed to adequately plan on how the learners ideas would be harmonised. The implication of this is that the planned lessons might lead to learners having disjointed ideas during implementation. There is need therefore to assist teachers of Mathematics to move beyond planning for only procedural tasks by strengthening their capacity to understand that constructivist approaches entail nurturing a conducive environment for knowledge creation.

h) Physics

Figure 82 shows Physics results regarding planning for lesson development activities. The findings disclose that there was inadequate indication of planning for lesson development activities in line with constructivist tenets at both senior (0%) and junior (25%) levels. Additionally, there were no plans for consolidation at senior level; however, the junior level had outstanding plans for consolidation as indicated by the 100%.

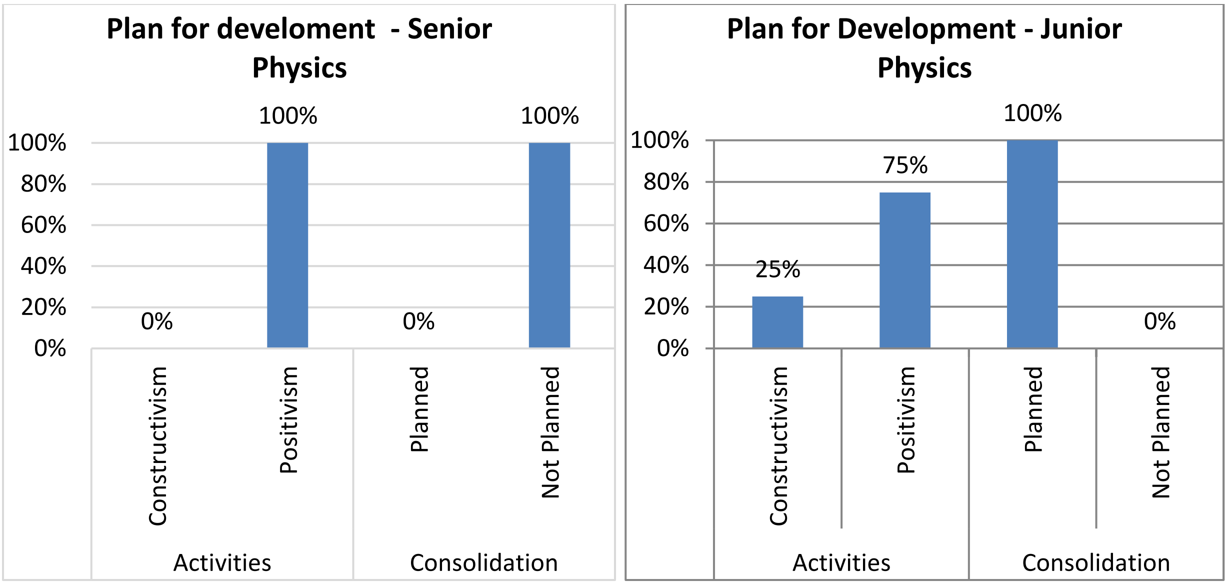
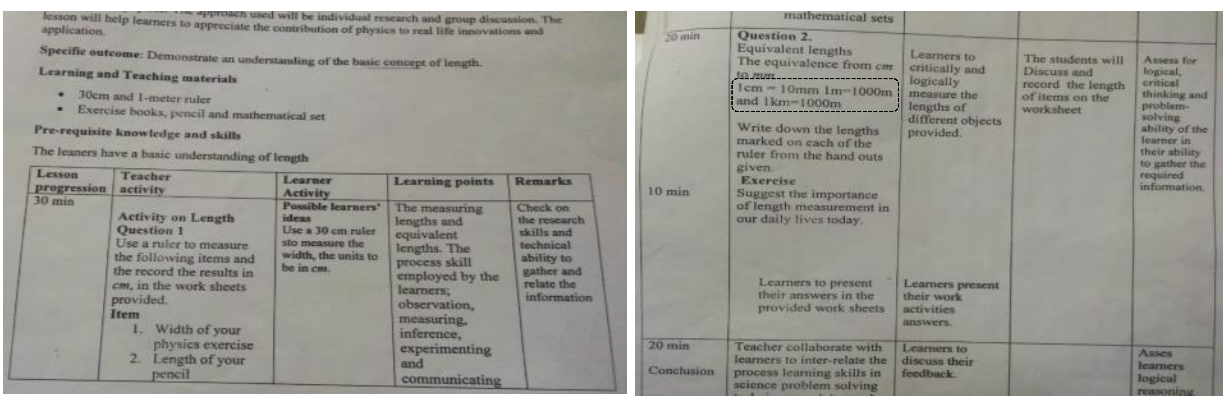


Figure 82 Plan for Development - Senior & Junior Physics

Despite having planned for key questions and scenarios in lesson introduction tasks, the lesson development activities showed very poor constructivist orientation at both senior and junior levels. This meant that the planned activities under lesson development in most lessons did not have opportunities to nurture desired skills. A case in point showing the lesson development activities is that of a grade 8 Physics lesson shown in Figure 83:



... approach used will be individual research and group discussion. The lesson will help learners to appreciate the contribution of physics to real life innovations and application.

Specific outcome: Demonstrate an understanding of the basic concept of length.

Learning and Teaching materials

- 30cm and 1-meter ruler
- Exercise books, pencil and mathematical set

Pre-requisite knowledge and skills

The leaners have a basic understanding of length

Lesson progression	Teacher activity	Learner Activity	Learning points	Remarks
30 min	**Activity on Length Question 1** Use a ruler to measure the following items and the record the results in *cm*, in the work sheets provided. **Item** 1. Width of your physics exercise 2. Length of your pencil	**Possible learners' ideas** Use a 30 cm ruler sto measure the width, the units to be in cm.	The measuring lengths and equivalent lengths. The process skill employed by the learners; observation, measuring, inference, experimenting and communicating	Check on the research skills and technical ability to gather and relate the information

	mathematical sets			
20 min	**Question 2.** Equivalent lengths The equivalence from *cm* to *mm* 1cm = 10mm 1m=1000m and 1km=1000m Write down the lengths marked on each of the ruler from the hand outs given.	Learners to critically and logically measure the lengths of different objects provided.	The students will Discuss and record the length of items on the worksheet	Assess for logical, critical thinking and problem-solving ability of the learner in their ability to gather the required information.
10 min	**Exercise** Suggest the importance of length measurement in our daily lives today. Learners to present their answers in the provided work sheets	Learners present their work activities answers.		
20 min Conclusion	Teacher collaborate with learners to inter-relate the process learning skills in science problem solving	Learners to discuss their feedback.		Asses learners logical reasoning

Figure 83: Sample lesson Plan for Planned Lesson Activities on Development

The activities in the lesson above did not provide good opportunities for learners to construct their own knowledge. The activities were planned in such a way that the teacher needed to take centre stage in the lesson. Additionally, one of the conversions indicated in the encircled area was wrongly presented. This might have been due to either influence from textbooks or inadequate content knowledge on the part of the teacher.

The observation that the lesson development activities were not planned in line with constructivist tenets could be an indication that there were struggles to change from positivism to constructivism.

The reason for this could have been inadequacies in curriculum understanding in relation to content and pedagogy. The implication of this is that the planned lesson activities in Physics did not provide opportunities to learn, which would eventually result in delivery of lessons that would not support acquisition of skills needed in contemporary and future societies. In terms of reinforcing ideas so that there is understanding, the senior level showed poor indication whilst this was remarkably done at junior level. In order to improve in this aspect, teachers need to develop skills for comprehensive understanding of curriculum intentions as regards to content and pedagogical aspects through professional development activities. With plans on how different ideas, solutions and explanations would be reinforced in Physics implied that misconceptions were taken care of and this eventually would result into effective delivery and lesson outcome attainment.

In summary planning for lesson development resonated around aspects of constructivism, positivism and consolidation across all the lessons in the survey. The major findings were that planning for lessons was in conformity with constructivist approach in 43% of the lesson plans while 57% of them were more or less positivist in nature. Further, 73% of the lesson plans indicated consolidation activities during lesson development. This is shown in Figure 84.

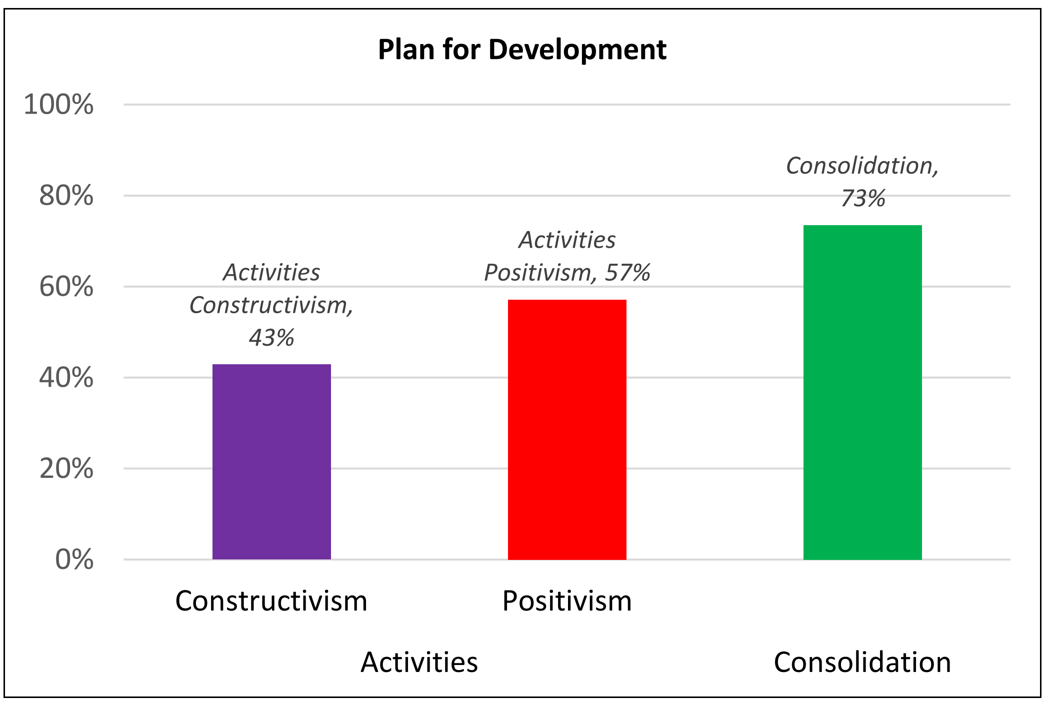


Figure 84: Summary on Planning for Lesson Development – All subjects

The observation that generally very few planning for lessons development activities (43%) show-cased constructivism aspects indicates the up-hill battle teacher education has to conquer as they voyage the STEM Education. This voyage is mostly being hampered by the stereotyped educational organization structure which is predominantly positivist (57%) in the country since independence as an inherited system. However, the 43% attainment should be viewed and appreciated as a paradigm shift towards constructivism in the way of learning in the journey hence require consistent support and reinforcement.

In terms of lesson consolidation, the 73% score meant that there were deliberate plans on how to confirm different viewpoints and explanations emanating from the learners hence attaining lessons with reinforced conceptual understanding. This approach requires reinforcement and sustenance amongst educationists at all levels including teacher preparation institutions and professional development fora.

4.1.4.5. Planning for Lesson Conclusion

A lesson arises from three variables namely curriculum, teacher and learner reflux. All the three play a key role in the conclusion phase. The correct mix of these and deviations from which will always affect the quality of a lesson. At the end of the lesson, the curriculum is a centre-piece of attraction from two viewpoints namely the teacher aspect with the objective intention and the learner aspect from the expected outcomes. Lesson conclusion should also speak to the introduction. Lessons progress from the introduction stage through to development and conclusion stages. Effective lesson conclusions do not just happen, they must be prepared for. Therefore, teachers have to plan on how they will end their lessons. In lesson conclusion, highlights of important lesson concepts must be summarized. . Therefore, planning for lesson conclusions should include explanations of how the lessons main points would be recapitulated. The lesson conclusion plans should be explicit on what the teacher and the learners would be doing during this stage of the lesson Planning for lesson conclusion is vital as it helps to provide understanding on how the lesson overview will be consolidated. There are many ways in which lesson conclusion can be planned for to take place. In this research the plan for lesson conclusion focused on the summary and evaluation components. Lesson summary plans should include strategies on how the information covered in relation to the lesson outcomes will be briefly explained. Evaluation as an aspect of lesson conclusion assesses the quality of teaching and learning immediately after the process. Both lesson summary and evaluation help to identity the content areas that may need to help to identity the content areas that may need to be revisited.

a) Agricultural Science

Figure 85 shows the planning for lesson conclusion results for Agricultural Science. Senior level lessons had 33% plans for summarizing and junior lessons where all planned for. None of the lessons translating into 0% of the planned lessons at senior indicated how the lessons were going to be evaluated while all the junior lessons had indicated how the lessons would be summarised and evaluated.

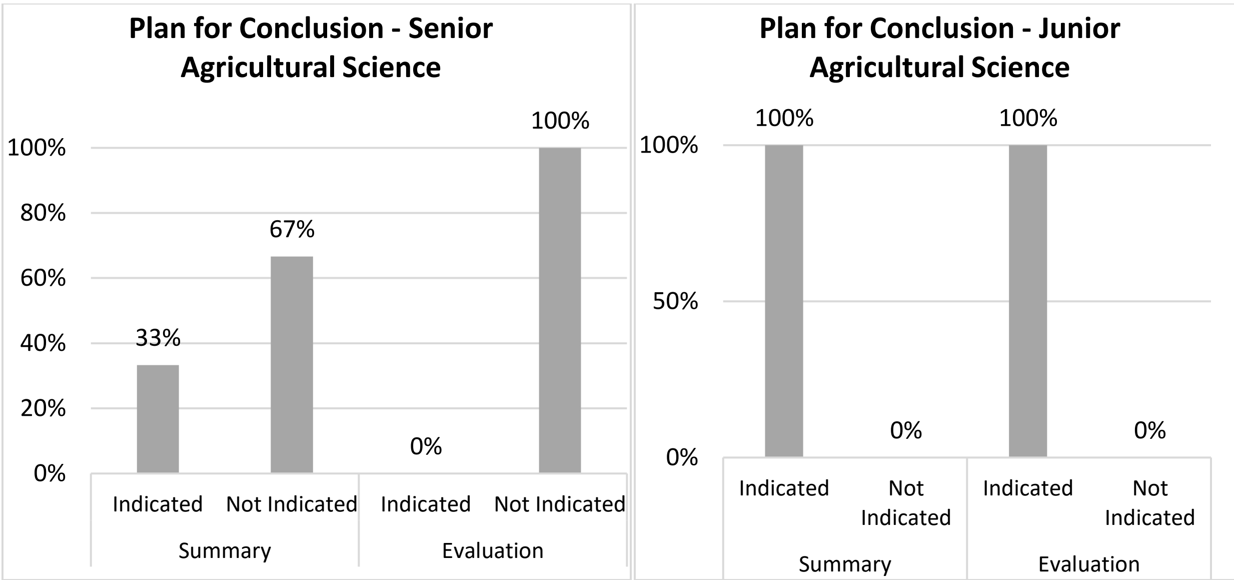


Figure 85: Plan for Conclusion Senior and Junior Agricultural Science

The planning for lesson conclusion results for Agricultural Science showed that at senior level there was poor planning for lesson summaries and lesson evaluation whilst at junior level there was outstanding planning for lesson conclusion and evaluation. For the lessons that had planned for lesson summaries and evaluation it entailed an understanding that the lesson needed to be concluded. Although theoretically these plans scored highly, there were however, deficiencies in the organization of lesson conclusion as shown below:

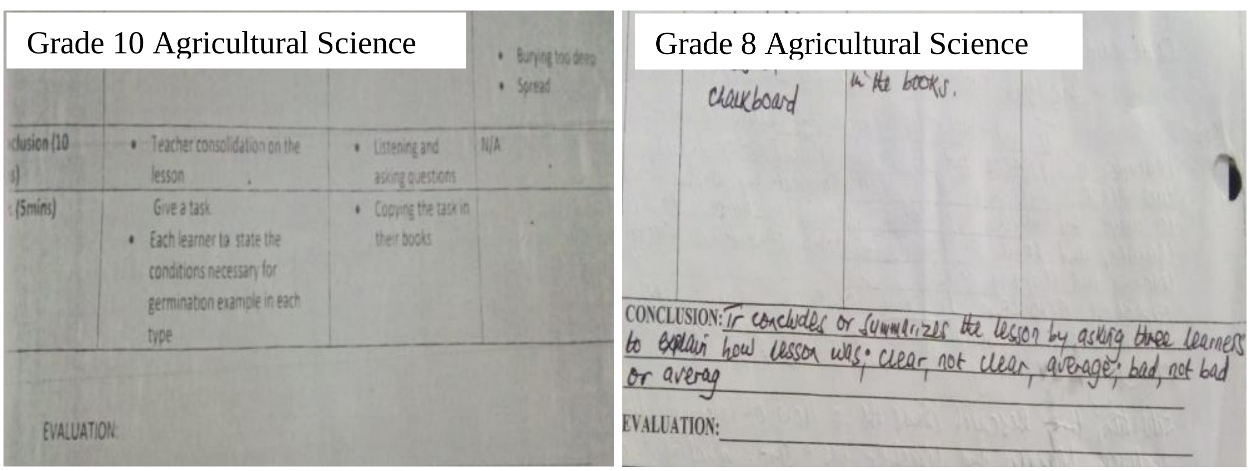


Figure 86: Planning for Lesson Conclusion - Senior and Junior Agricultural Science

In the first case of Grade 10 Agricultural Science, in Figure 86 above it shows that the teacher was to consolidate the lesson. In this case if the teacher consolidates the lesson as a conclusion, it will be difficult to assess the achievement of the lesson intent. The other Grade 8 Agricultural Science case states that the teacher would ask 3 learners to *"explain whether the lesson was clear, not clear,* *average or bad*". The statement is more of an evaluation of a lesson than summary. This shows incapability to distinguish between summary and evaluation on the part of the teacher as well as what constitutes them. The implication of this could be that it would be complicated to determine whether the lesson intents were consummated. As for the lessons that did not plan for lesson summaries and evaluation, it could have been as a result of insufficient, competencies and skills. The implication of this could be that it would be difficult to know whether the lesson intentions were attained and what possible interventions to take to alleviate the challenges if any as the lesson was delivered. Therefore, Agricultural Science teacher's capacity needs to have intensified professional development activities in order to understand lesson planning aspects.

b) Biology

The Biology results in Figure 87 on planning for lesson conclusion showed that at both senior and junior levels lessons indicated planned lesson summaries (100 %). With regards planned lesson evaluation, 33 % at senior level had indicated planning whereas at junior level all lessons had not planned for lesson evaluation.

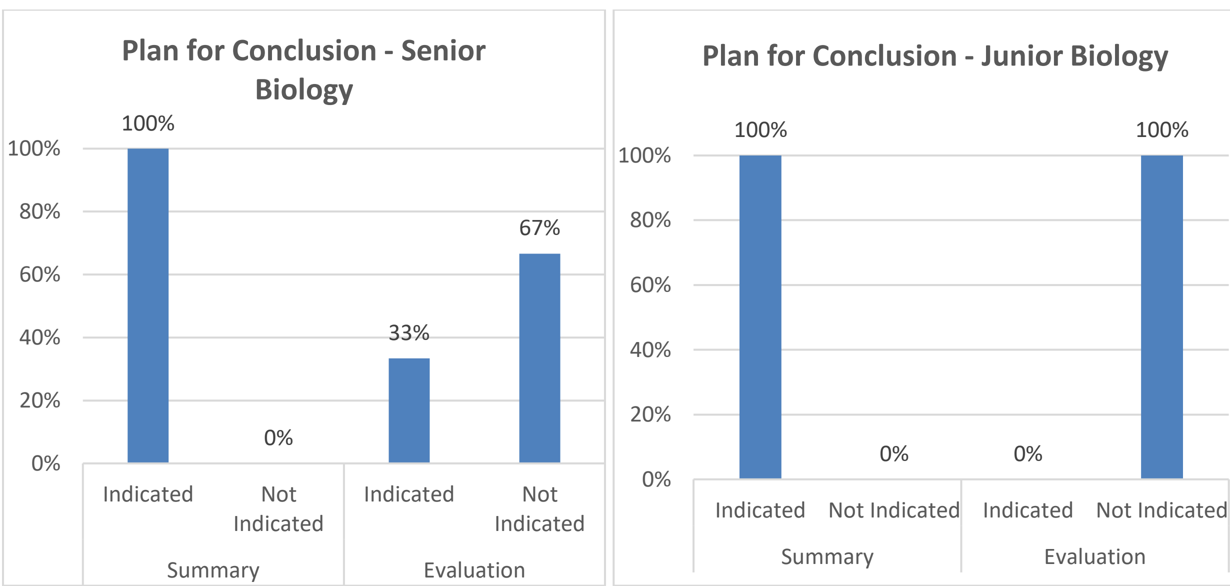


Figure 87: Planning for Conclusion Senior and Junior Biology

The Biology results on planning for lesson conclusion on one hand, showed an outstanding indication on planning for lesson summaries at both junior and senior levels. On the other hand, the senior level had poor plans for lesson evaluation as opposed to the junior level that had remarkable planning as regards to lesson evaluation. Cases in point amongst others were as shown below:

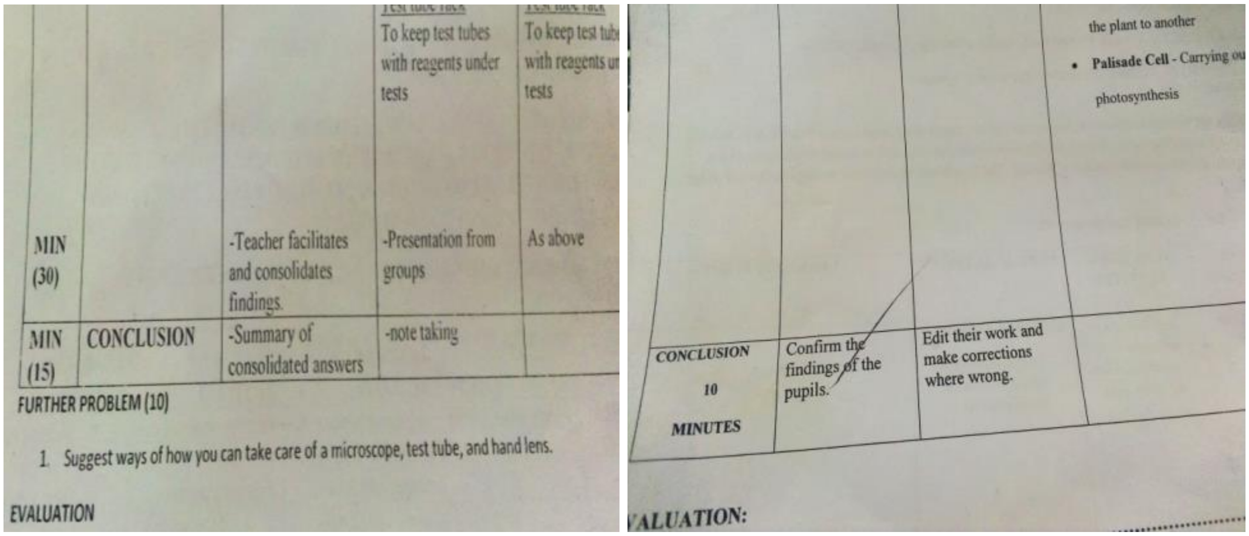


Figure 88: Sample Case for Planning for Conclusion and Evaluation

The first case in Figure 88 shows that there was not only understanding that conclusion was part of the lesson stages but also what constitutes a lesson conclusion. From this, it entails that pedagogical skills in terms of lesson planning were evident. In the second case, there was understanding that a lesson needed to have a conclusion. However, the constituents of the conclusion planned were not appropriate. The confirmation of learners' findings should be dealt with under lesson development. The plan for conclusion should have a connection to the lesson objectives. The second case would not easily help to determine whether or not the lesson objectives were met. Lesson conclusion should relate to summarizing and evaluating the lesson intent. The insinuation as regards to the Biology lessons that had planned for lesson summaries and evaluation was that in some cases there were appropriate content and pedagogical skills in lesson planning which enabled them to plan for the lesson summaries and evaluation. This would ultimately help in reviewing the success of the lesson and the necessary clarifications to make. To improve the lesson planning skills in Biology, there is need to enhance teacher professional activities by collaboratively planning lessons, and engaging in subject specific activities that would enrich the pedagogical competencies of the teachers.

c) Chemistry

The Chemistry results as indicated in Figure 89 on planning for lesson conclusion showed that at senior level, 50 % of the lesson plans had lesson summaries and evaluation planned. For the junior level all the lessons had lesson summary planned but not lesson evaluation.

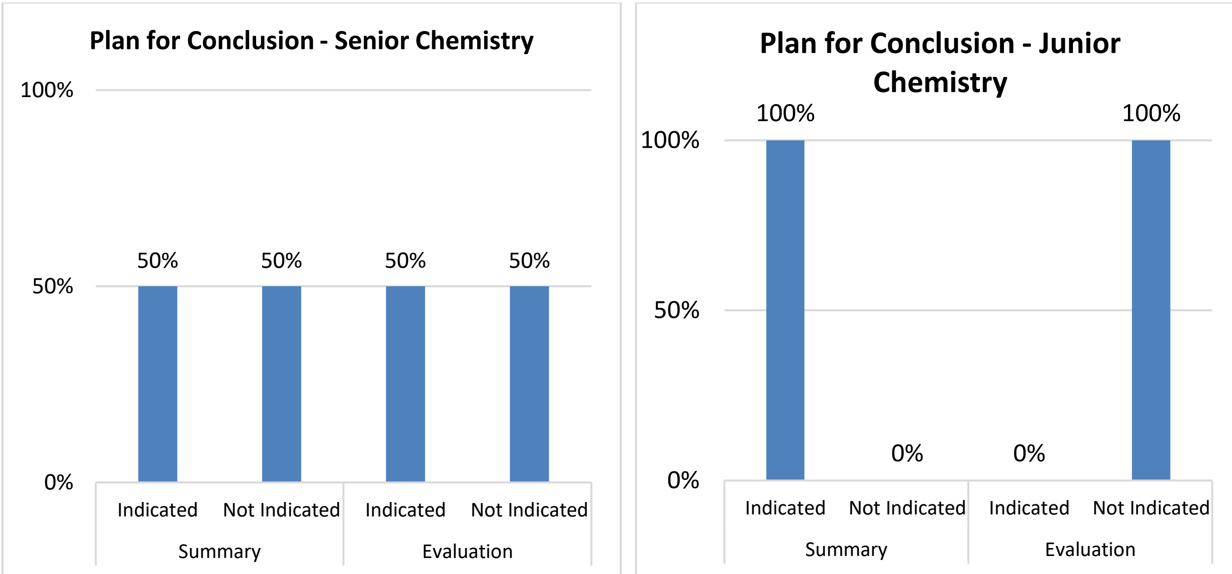


Figure 89: Planning for Conclusion Senior and Junior Chemistry

The above results showed that at senior level there was average planning on lesson summaries and evaluation. For the junior level the plans for lesson summary was outstanding whilst that of lesson evaluation was poor. On one hand, for the lessons that had planned lesson conclusions it meant that there was understanding of lesson planning aspects as regards to lesson conclusion and its constituents. The implication of this is that there would not only be easy assessment of whether the lesson intentions were achieved but also there would be delivery of well-thought-out lesson conclusions which would help take into account the challenges that will still exist after the lesson if any. On the other hand, the reason for the lessons that did not plan for lesson conclusions could be inadequate understanding that a lesson requires to have a conclusion. Additionally, it could also mean that there was inability to differentiate between summary and evaluation as well as what constitutes them. The implication of this could be that it would be challenging to know whether the lesson intentions were achieved and what possible future interventions to take to remedy the challenges. Therefore, the fact that teachers of Chemistry need to understand what constitutes a lesson conclusion, how to organize information in lesson summary and evaluation as part of the lesson conclusion cannot be understated. To improve the Chemistry lesson planning process which includes planning for lesson conclusion there is need for strengthened Chemistry professional development activities.

d) Computer Science

The results for planning for lesson conclusion in Computer Science are shown in Figure 90. The findings indicate that 60 % of the lesson plans at senior level and 100 % at junior level had plans for summarizing. As regards to lesson evaluation, 20% of the senior and 50 % at junior level indicated how the lessons were going to be evaluated.

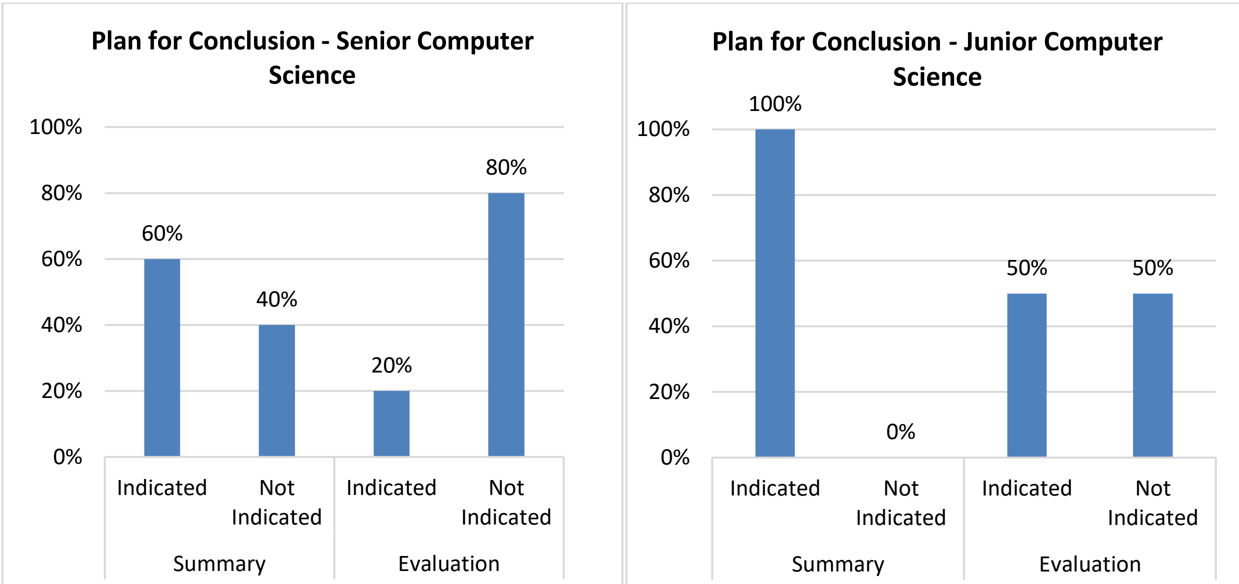


Figure 90: Planning for Conclusion - Senior and Junior Computer Science

The results for planning for lesson conclusion in Computer Science showed that some lessons at Grade 10 senior level had plans for summarizing while there was low indication on how the lessons were going to be evaluated. For the junior secondary level, there were remarkable plans for lesson summarizing with an average indication on how the lessons were to be evaluated. On one hand, the planning for lesson summaries and evaluation suggested that there was understanding of what the lesson conclusion was and what aspects it should contain. The implication of this could be that it would be easy to gauge whether the lesson objectives were accomplished or not. On the other hand, the reason for none indication of lesson conclusion plans could be that teachers were not able to understand that a lesson needed to be completed using a lesson conclusion. Other than that, it could also mean that there was inability to distinguish between summary and evaluation as well as what constitutes them. The implication of this is that it would be challenging to know whether the lesson intentions were attained and what possible future interventions to take to address the challenges. Therefore, Computer Science being a new curriculum dimension in STEM needs intensified professional development activities in order to equip teachers with more understanding on lesson planning aspects.

e) Design and Technology

Figure 91 presents Design and Technology results on planning for lesson conclusion. The findings disclose remarkable planning for lesson summary at both senior (100%) and junior (83%) levels. However, none of the senior lesson plans had indicated plans on how the lessons were to be evaluated and only 17% of the junior ones had lesson evaluation plans.

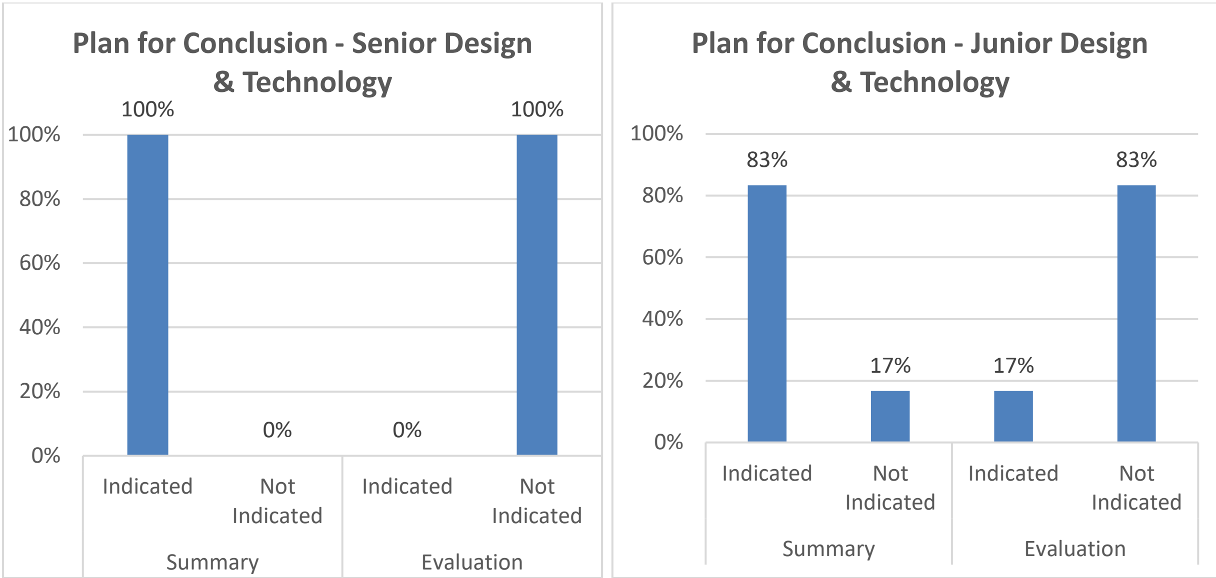


Figure 91: Planning for Conclusion Senior & Junior Design and Technology

The remarkable results on planning for lesson summary might have been an indication that the majority of teachers had appropriate content and pedagogical skills in lesson planning as they were able to suitably plan on how their lessons would be summarized. However, evaluation of lesson from the point of view of learners remains a challenge to most teachers. The extracts below show some cases of clearly planned lesson summaries:

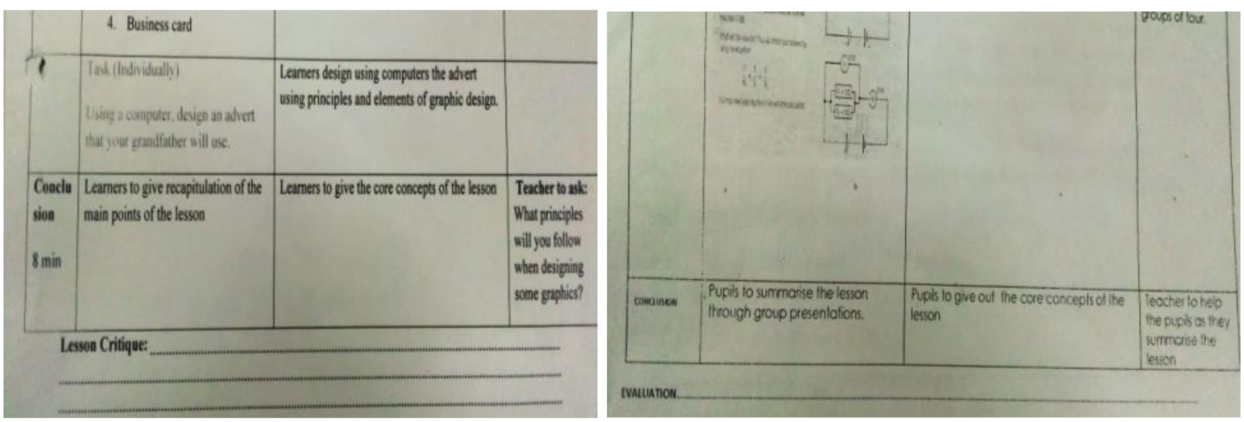
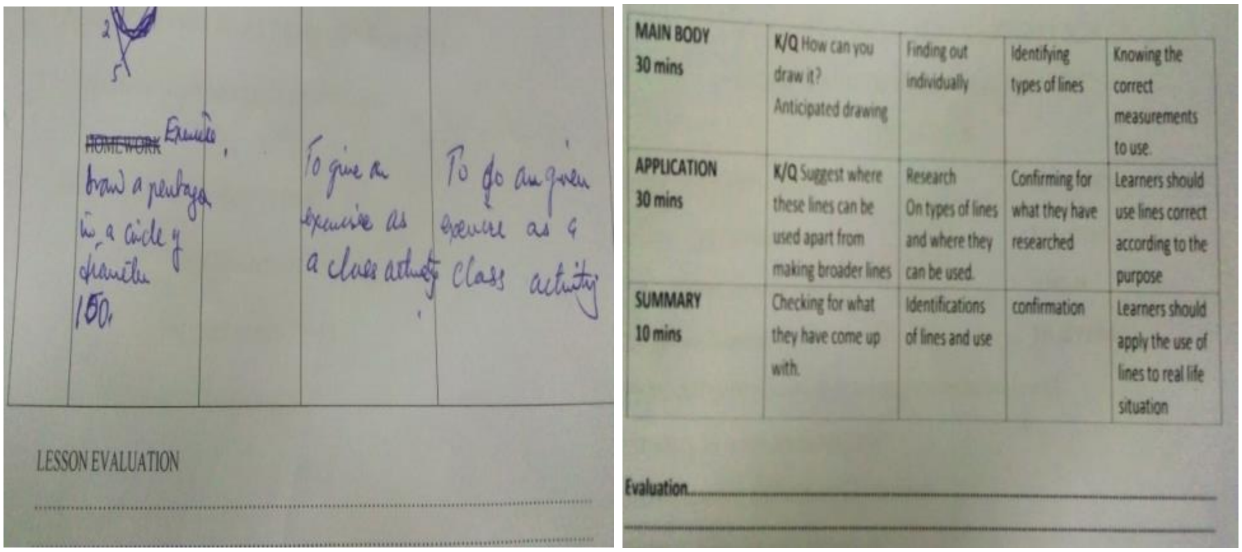


Figure 92: Sample Case - Planning for Conclusion in Design and Technology

The lesson conclusion cases above show clearly the plans on how the main points of the lessons were to be summarized. The lesson conclusion plans in Figure 92 also showed distinctly what the role of the teacher and the learners would be during this stage of the lesson. The above lesson closure plans would make it easy during lesson implementation to determine whether learners needed additional practice or whether there was need to go over some lesson aspects. However, in other cases the lesson conclusions planned for were not clearly done as shown in Figure 93 below



HOMEWORK Exercise, Draw a pentagon in a circle of diameter 150.

To give an exercise as a class activity

To do an given exercise as a class activity

LESSON EVALUATION

MAIN BODY 30 mins	K/Q How can you draw it? Anticipated drawing	Finding out individually	Identifying types of lines	Knowing the correct measurements to use.
APPLICATION 30 mins	K/Q Suggest where these lines can be used apart from making broader lines	Research On types of lines and where they can be used.	Confirming for what they have researched	Learners should use lines correct according to the purpose
SUMMARY 10 mins	Checking for what they have come up with.	Identifications of lines and use	confirmation	Learners should apply the use of lines to real life situation

Evaluation.........

Figure 93: Sample Case of Variations in Planning for Conclusion in Design and Technology

The cases in Figure 93 show that in one lesson an exercise was planned as conclusion and in the other case the conclusion was in principle simply reinforcement of learner ideas and not summarizing. This should have been part of the planned lesson activities under the development stage. The reason for the inappropriate planned conclusion activities could be that teachers did not know what should be included in lesson conclusion. The implication of this could be that when the lessons are delivered the extent of lesson objective attainment would be difficult to assess. It is essential, therefore, that teachers of Design and Technology engage in subject specific professional enhancement activities so that they learn from one another and enrich their lesson planning skills especially on lesson conclusions.

f) Hospitality and Tourism

The Hospitality and Tourism results as regards to planning for lesson conclusions are shown in Figure 94. The findings indicate that at senior level the lesson summary was planned for in all the lessons, whereas at junior level, there were no such plans. In terms of lesson evaluation none of the lessons at both senior and junior levels had planned to evaluate the lessons as indicated by the 0%.

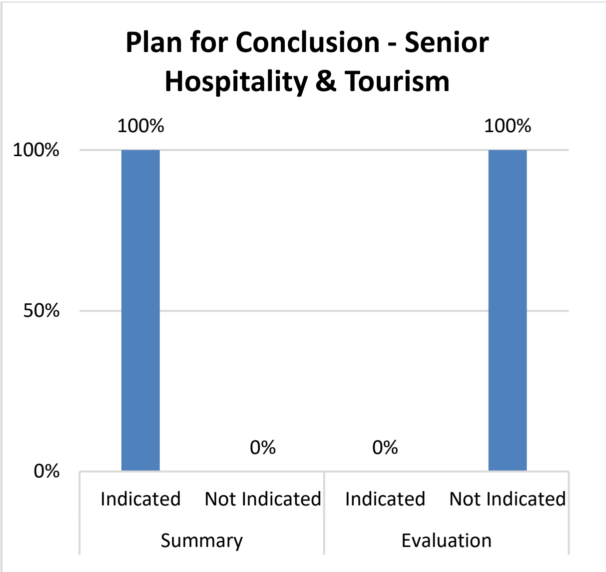


Figure 94: Planning for Conclusion for Hospitality and Tourism – Senior and Junior

The non-planning of lesson evaluation at both senior and junior levels raises concern because it entails that there was no assessment of the teaching and learning after the learning process. Lesson evaluation is an important conclusion aspect as it helps to assess the quality of teaching and learning. There is need therefore, for teachers of Hospitality and Tourism to engage in professional development activities in order to strengthen their lesson planning skills.

g) Mathematics

The Mathematics results regarding planning for lesson conclusion are as shown in Figure 95. The findings reveal that at senior level 40% of the lesson plans had summaries planned for while at junior the plans were outstanding at 100%. The planning for evaluation at both senior and junior levels was below average as indicated by 20% and 33% respectively.

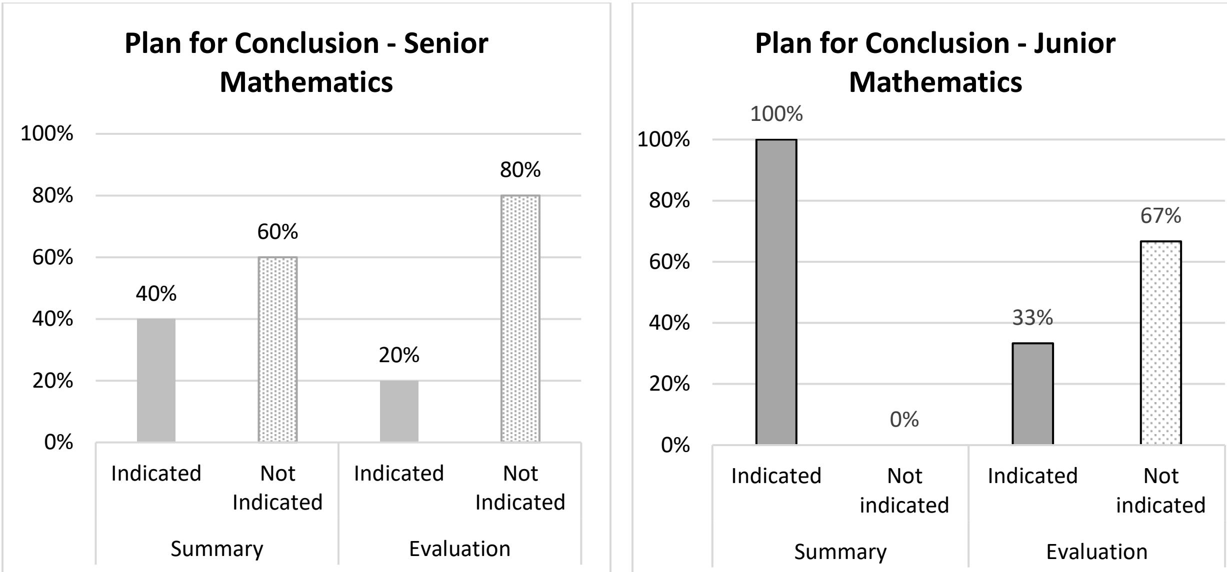


Figure 95: Plan for Conclusion Senior and Junior Mathematics

Despite having planned for lesson conclusion, the actual contents of the summary and evaluation were not suitable to effectively conclude the lessons. For instance, in one lesson plan it was stated: "*To add fractions, follow the following steps: Find LCM, divide each denominator into LCM and multiply the result by the numerator".* This kind of conclusion does not clearly state how the main points of the lesson would be summarised thereby making it difficult to determine whether the learners understood the concept or not. Another illustration of a lesson conclusion is shown in Figure 96 which shows only the lesson summary part of and not the evaluation.

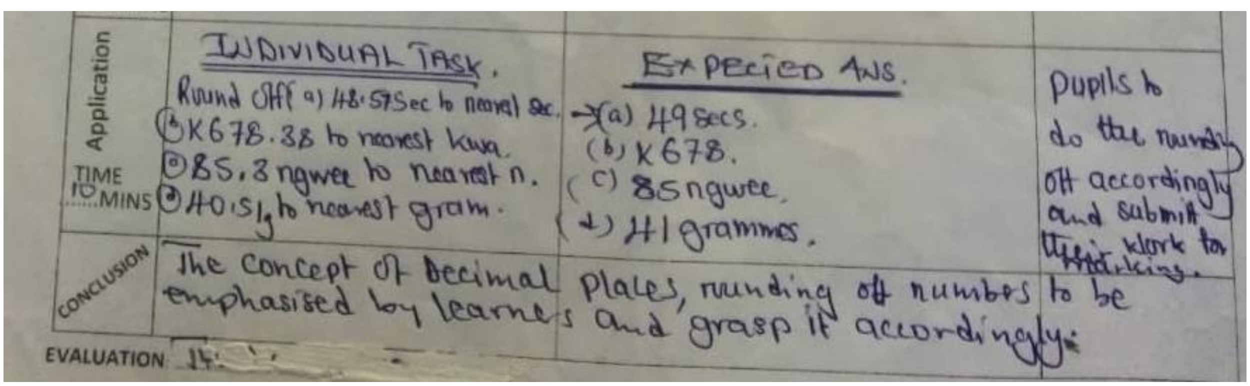
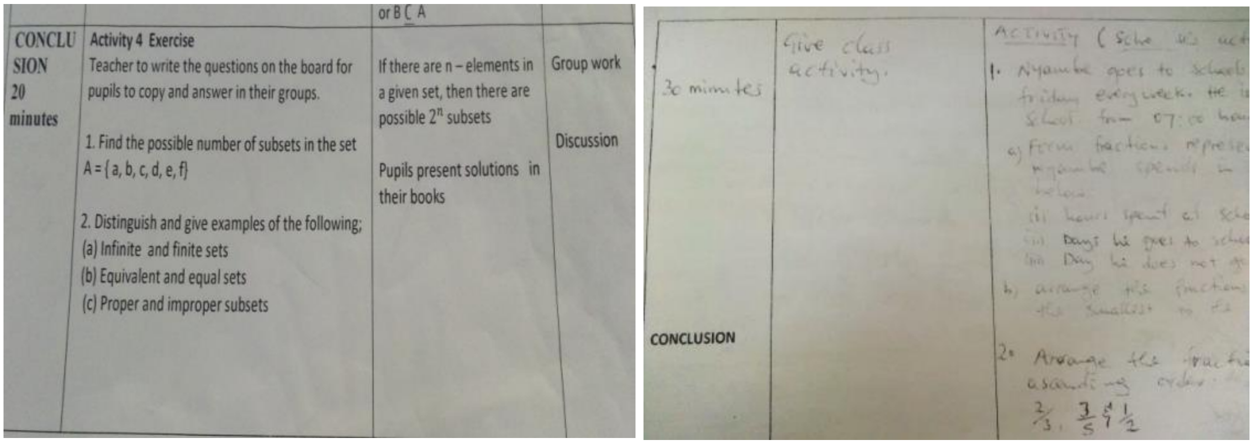


Figure 96: Excerpt on Conclusion

Further, there were still challenges shown in what should constitute lesson conclusions. The planned conclusions in some of the lessons showed the usual practice of giving numerical exercises as an aspect of lesson summary as shown in Figure 97.



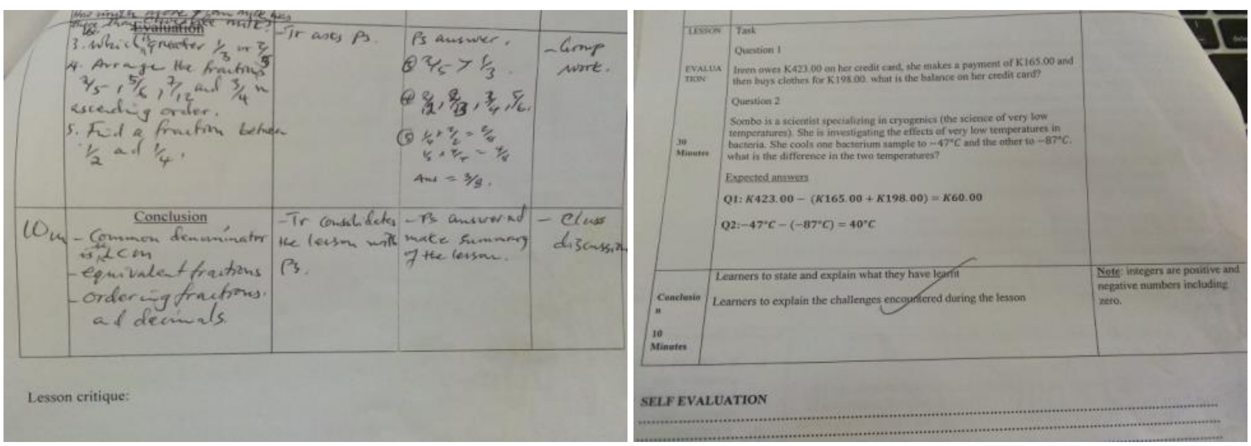
or B ⊂ A

CONCLUSION 20 minutes	Activity 4 Exercise Teacher to write the questions on the board for pupils to copy and answer in their groups. 1. Find the possible number of subsets in the set A = {a, b, c, d, e, f} 2. Distinguish and give examples of the following; (a) Infinite and finite sets (b) Equivalent and equal sets (c) Proper and improper subsets	If there are n – elements in a given set, then there are possible 2^n subsets Pupils present solutions in their books	Group work Discussion

30 minutes CONCLUSION	Give class activity.	ACTIVITY 1. Nyambe goes to school ... friday everyweek. He ... school from 07:00 hours ... a) Form fractions representing Nyambe ... below (i) hours spent at school (ii) Days he goes to school (iii) Days he does not go ... b) arrange the fractions ... the smallest to the ... 2. Arrange the fractions ... ascending order ... 2/3, 3/5, 1/2

Figure 97: Sample case for Plan for Conclusion in Mathematics

The above cases are a clear indication that there were misunderstandings in what should constitute the lesson conclusion. The implication of this was that the lesson contents planned if delivered that way would not adequately sum up the learning points of the lesson. Conversely, some of the Mathematics lesson conclusions planned for had aspects that were appropriate for concluding lessons as shown in the following cases (Figure 98).



	Evaluation 3. Which is greater 1/3 or 3/5 4. Arrange the fractions 3/5, 5/6, 7/12 and 3/4 in ascending order. 5. Find a fraction between 1/2 and 1/4.	–Tr asks Ps.	Ps answer. 3/5 > 1/3 Ans = 3/8.	–Group work.
10m	Conclusion – Common denominator is LCM – equivalent fractions – ordering fractions and decimals.	–Tr consolidates the lesson with Ps.	–Ps answer and make summary of the lesson.	–Class discussion.

Lesson critique:

LESSON	Task	
EVALUATION 30 Minutes	Question 1 Ireen owes K423.00 on her credit card, she makes a payment of K165.00 and then buys clothes for K198.00. what is the balance on her credit card? Question 2 Sombo is a scientist specializing in cryogenics (the science of very low temperatures). She is investigating the effects of very low temperatures in bacteria. She cools one bacterium sample to −47°C and the other to −87°C. what is the difference in the two temperatures? Expected answers Q1: K423.00 − (K165.00 + K198.00) = K60.00 Q2: −47°C − (−87°C) = 40°C	
Conclusion 10 Minutes	Learners to state and explain what they have learnt Learners to explain the challenges encountered during the lesson	Note: integers are positive and negative numbers including zero.

SELF EVALUATION

Figure 98: Sample case meeting minimum requirements in Mathematics Lessons

The planned lesson conclusions in the above lesson plan cases showed the role of the teacher and learners during this particular stage of the lesson and the content of the conclusion was linked to the lesson outcomes. This means that for these lessons there was understanding of what should constitute lesson conclusions. The implication of this is that there would not only be easy assessment of whether the lesson objectives were achieved but also delivery of well thought lesson conclusions which would help take into account the challenges that will still exist after the lesson. It is therefore, imperative that teachers of Mathematics understand what constitutes a lesson conclusion, how to organize information in lesson summary and evaluation as part of lesson conclusion. To enrich the Mathematics lesson planning process, which includes planning for lesson conclusion there, is need for strengthened communities of practice within the school which should engage in activities such as collaborative planning of lessons. Other than that teachers of Mathematics can further be capacity built in terms of constituents and information to be included in the lesson conclusion during the planning process.

h) Physics

Figure 99 shows the Physics results on planning for lesson conclusion. The results show that all the lessons at senior level did not have summary indicated but had lesson evaluation as is respectively indicated by the 0% and 100%. For the junior level, 50% of the Physics lesson plans contained summaries and evaluation while the rest did not have.

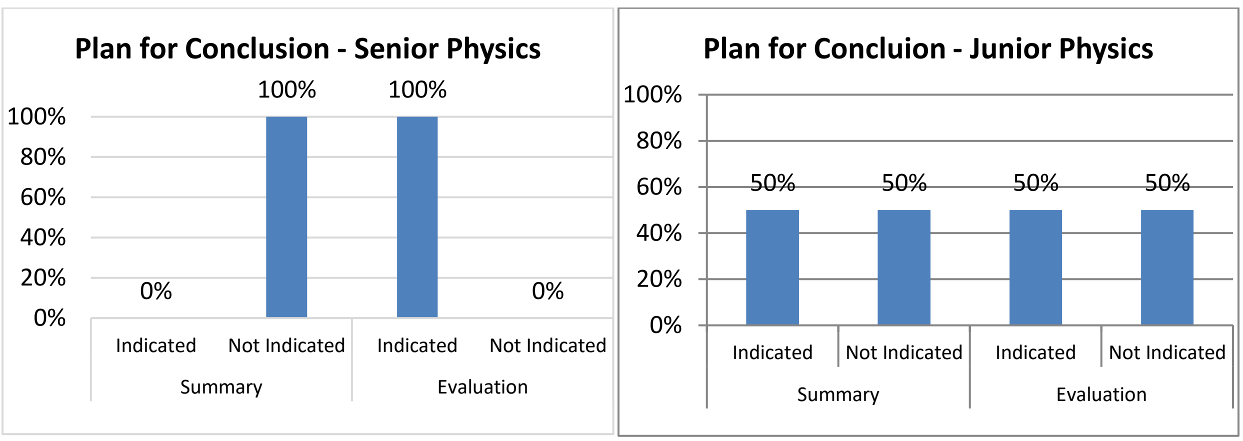
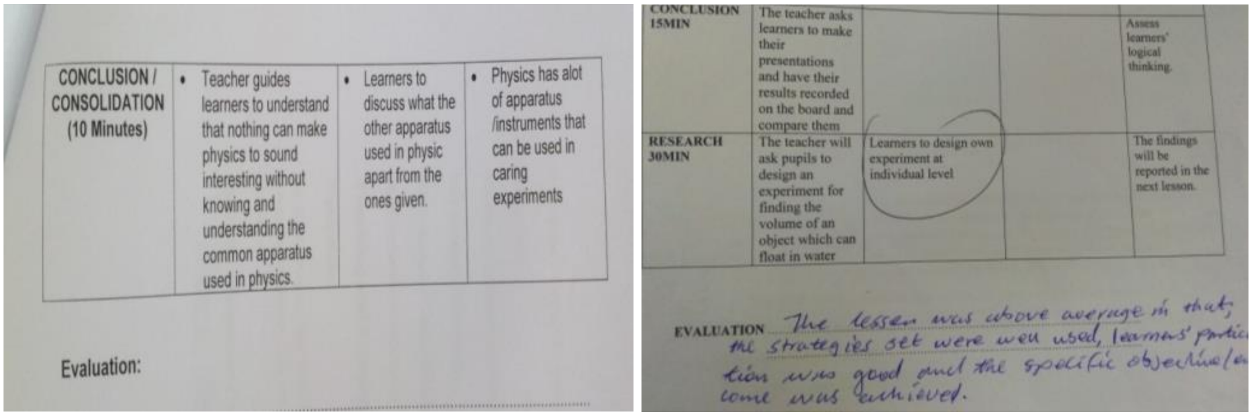


Figure 99: Plan for Conclusion in Senior and Junior Physics

The reason for non-indication of plans for lesson summary and evaluation for the lessons under discussion could be inability to construct suitable activities for concluding a lesson on the part of the teachers. This finding points to the inadequate pedagogical or content knowledge skills exhibited by the teachers. As alluded to earlier, lesson conclusion plays a vital role in either winding up a lesson or setting the tone for the next lesson. The following caption, in Figure 100, illustrates the planned conclusion for some lessons observed:



CONCLUSION / CONSOLIDATION (10 Minutes)	• Teacher guides learners to understand that nothing can make physics to sound interesting without knowing and understanding the common apparatus used in physics.	• Learners to discuss what the other apparatus used in physic apart from the ones given.	• Physics has alot of apparatus /instruments that can be used in caring experiments

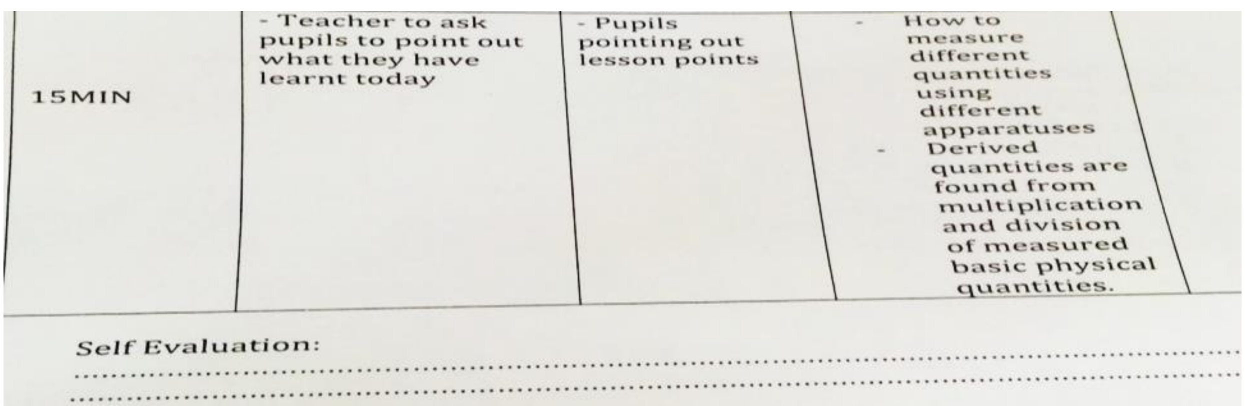
Evaluation:

CONCLUSION 15MIN	The teacher asks learners to make their presentations and have their results recorded on the board and compare them			Assess learners' logical thinking.
RESEARCH 30MIN	The teacher will ask pupils to design an experiment for finding the volume of an object which can float in water	Learners to design own experiment at individual level		The findings will be reported in the next lesson.

EVALUATION The lesson was above average in that, the strategies set were well used, learners' partic tion was good and the specific objective/o come was achieved.

Figure 100: Sample case of Incorrect Lesson Conclusion in Physics

The two lesson conclusion cases show positivist approach as the plans indicate that the teacher takes the centre stage during lesson conclusion. From the cases above what constituted the lesson conclusion plans should have been part of the lesson development. From the captioned Physics lesson plan conclusions, it was evident that there were not only misunderstandings in what should constitute the lesson conclusion but also inadequate lesson planning skills. The implication of not planning the lesson conclusion could be that correct lesson learning points would not be synopsized thereby making it difficult to clearly assess the achievement of the lesson objectives. Further implications would be that there would be challenges in employing probable impending interventions as antidotes to the learning difficulties learners faced. It is therefore, essential to not only plan on how lessons would be concluded in STEM learning but also to state what the role of learners and the teacher would be during this stage of the lesson. Some of the lesson plans clearly indicated the role of the teacher and learner as shown in Figure 101:



15MIN	- Teacher to ask pupils to point out what they have learnt today	- Pupils pointing out lesson points	- How to measure different quantities using different apparatuses - Derived quantities are found from multiplication and division of measured basic physical quantities.	

Self Evaluation: ……………………………………………………

Figure 101: Sample Case of a good plan for Conclusion in Physics

In the case above the lesson had clearly indicated what the role of the teacher and learner would be during lesson conclusion. The implication of this is that the lesson learning points would easily be summarized thereby helping to gauge whether the lesson purpose was accomplished or not. A good plan for lesson conclusion need not only have ways on how learners will organize information in meaningful contexts in their minds but also how they will explain what they would have learnt and its application to daily life. To help in planning for lesson conclusion, there is need for teachers of Physics to intensify collegiality by planning lessons collaboratively and holding Physics teacher group meetings to share better lesson planning skills. Further, the teachers could still be capacity built in terms of lesson planning skills through subject associations and strengthened CPD activities.

Summary of Planning for Conclusion

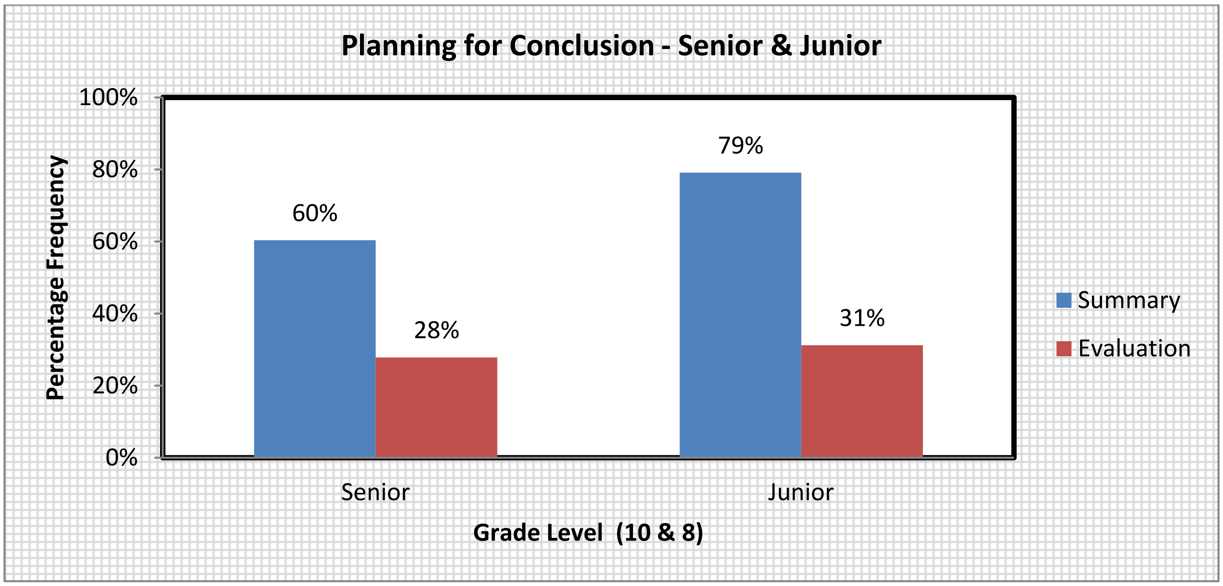


Figure 102: Summary of Planning for Conclusion

As referred to in the introductory part of this section, lesson conclusion is just as important as the other parts of the lesson because it is at this stage that the curriculum, teacher and learner aspects are intertwined. It was found in this research that generally across all the subjects the aspects of lesson conclusion were not meeting the minimum standards as shown in Figure 102. This will conversely lead to inadequate attainment of learning outcomes. Therefore the teacher should always consider the mix of the three as they plan the conclusion of the lesson.

4.1.5. Resource Materials

Resource materials are an important aspect regarded to help interpret and implement curricula. In today's educational process there are plenty of teaching and learning resources used to support lesson planning and delivery. However, in this context the focus of analysis as regards to the teaching and learning resources included print and e-resources as well as their appropriateness. Print resource materials include books, charts, encyclopaedias, magazines, dictionaries, newspapers, journals. E-resources are an inseparable part of educational system in this highly technological era. They play a prominent role in supporting teaching and learning. E-resources are those that require computer access or any electronic product that delivers a collection of data. Types of e-resources include online resources such as (e-journals, e-books, Multi-media, websites, and interlinked hyper-text documents) and portable resources (CD-ROM, Diskettes, Flash discs, tablets, and iPods). The following are the findings and analyses on resource materials across subjects and grades.

a) Agricultural Science

The Agricultural Science results as regards to the teaching and learning resources, as seen in Figure 103 show that at senior level 67 % of the lesson plans indicated resource materials and these were found to be appropriate. For the junior level all the lesson plans indicated resource materials to be used during the lesson. However, after analysis of the kind of materials, they were found to be inappropriate.

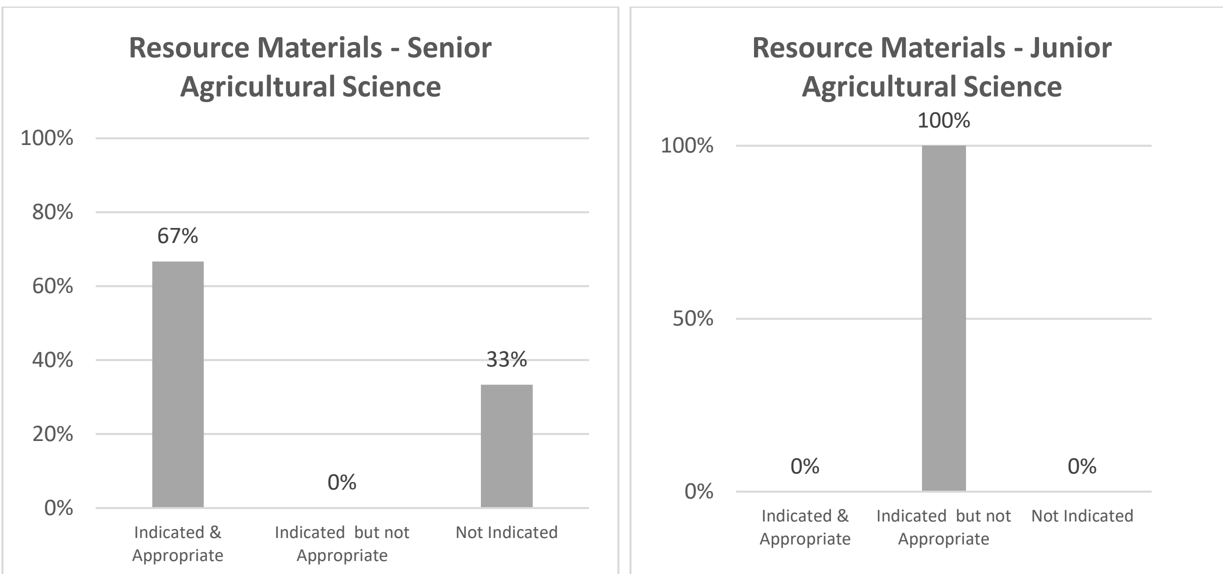


Figure 103 Resource Materials in Senior & Junior Agricultural Science

The indication of the resource materials, which were referred to during the lesson planning process means that teachers had good proficiencies that helped them, select appropriate resource materials and use them to plan lessons. The implication of this would be that varied information will be taken into consideration when planning for lessons hence the curriculum intentions would be well catered for and connect well with the lesson activities. Conversely, despite the consulted resource materials being appropriate all were print text and none of them were e-resources as shown in Table 17.

Table 17: Sample Resource Materials for Senior and Junior Agricultural Science

Resource Materials Consulted	
Print Resource	**E-resource Materials**
i. Mk Grade 8 ii. MK senior secondary science learners book pp44 iii. 2019 STEM Agricultural Science Transitional Curriculum iv. 2019 STEM Agricultural Science Transitional Syllabus v. Agricultural science pamphlet	None

The information in the table shows that all the resources that were consulted during the lesson planning process in Agricultural Science were print resources and none were e-resources. The internet can be a source of educational resources. The e-resources could considerably help teachers to explore widespread explorative learning ideas which could be included in lesson plans. This is why in the Zambian STEM Education Curriculum ICT is one of the mandatory components that should be undertaken by both teachers and learners. Teachers and learners need to be proficient in the access and use of the e-resources. The non-utilization of e-resources may have been non-existence of internet facilities, poor internet connectivity, and inadequate ICT competencies to use the resources. The implication of this is that teachers would not have a variety of information to help in the understanding of subject matter and in the formulation of appropriate key tasks for teaching and learning. It can also lead to limit the scope of the teaching and learning aids preparation. To help alleviate ICT challenges, basic ICT literacy skills should be a component in STEM teacher capacity building training courses. Further, an electronic repository needs to be developed where teachers and learners could access e-resources. To that effect, the Directorate of National Science Centre is currently developing the Learning Management Platform to be used by both teachers and learners for easy access and utilisation of resource materials. Furthermore, teachers need to have in depth study of teaching and learning resources through strengthened collaboration activities such as Lesson Study.

b) *Biology*

Figure 104 shows Biology results concerning teaching and learning resources referred to during planning for lessons. The findings revealed that at both senior and junior levels the non-indication of the resource materials was 67% and 50% respectively. Lesson plans that had teaching and learning resources indicated and those that indicated inappropriate ones were below average.

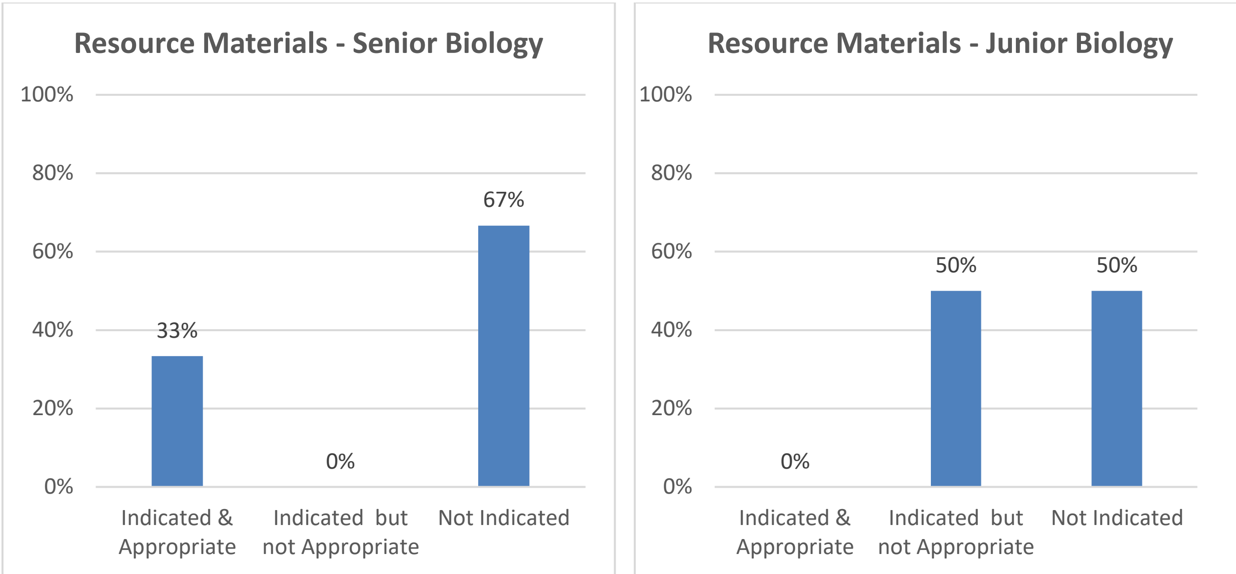


Figure 104 Resource Materials for Senior and Junior Biology

The reasons for not indicating resource materials could mean that there was no access to appropriate teaching and learning resources. Other than that it could also have meant inability to be resourceful in looking for materials that could contain the relevant information of what was to be taught and learnt. The implication of this could be that insufficient information would be gathered for use in the planning and delivery process. This may eventually impede the achievement of intended lesson outcomes. The resource materials indicated were all print materials as shown in the case below amongst others:

The common resource materials cited in most lesson plans were: *Biology 10 text book, Basics of Biology, and Complete Biology.* Others were: *Lisuba, MK Senior Secondary Chemistry, and MK Biology.*

The print materials consulted were not properly referenced. Another observation made was a mix-up of resource materials and teaching and learning aids. From the above listed resource materials there was no use of e-resources. This could have been due to lack of internet facilities and connectivity as well as lack of ICT skills. In STEM teaching and learning it is imperative that both teachers and learners should have basic ICT literacy skills in order to facilitate learning. Therefore the non-use of e-resources may imply a limitation in information needed to help in understanding the subject matter. Therefore, professional development activities should not only enhance content and pedagogical knowledge but also include enhancement of teachers’ basic ICT literacy skills.

c) *Chemistry*

The Chemistry results concerning teaching and learning resources, as seen in Figure105 showed 75% and 100% indication of appropriate resource materials at senior and junior levels respectively.

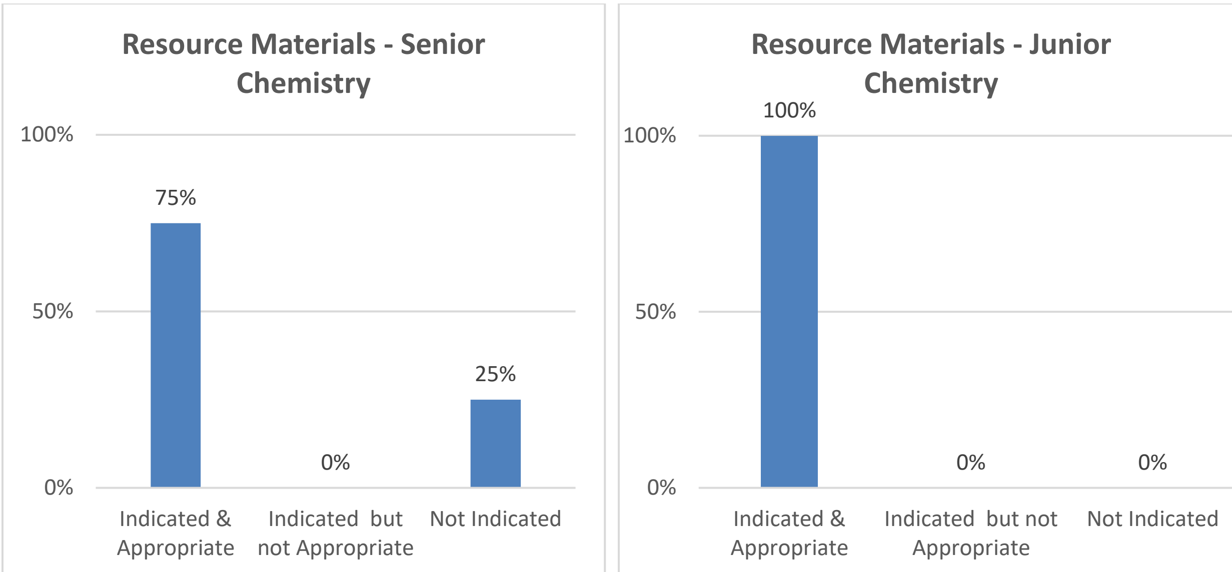


Figure 105 Resource Materials for Senior and Junior Chemistry

Having appropriate teaching and learning resources means that they are clearly curriculum-relevant and useful. It also means that they are framed in the wider context of the subject matter and suitable to the needs of the learners. The indication of appropriate teaching and learning resources on the Chemistry lesson plans may imply that the teachers understood the curriculum intentions and therefore, gathered adequate information about the concepts. Amongst the materials indicated on the lesson plans were: *Introduction to Chemistry pg. 49, MK Grade 10 Chemistry pupil's book, Modern Chemistry, Chemistry Connections to our changing world, and Advanced level Chemistry.*

The itemized teaching and learning resource materials consulted during planning for Chemistry lesson plans show that there was no use of e-resources. This could possibly be as a result of not only having no internet facilities but also due to poor internet connectivity. Additionally, inadequate ICT skills could have also caused none consultation of e-resources during the planning for Chemistry lessons. The implication of not consulting and using e-resources during lesson planning may be inadequate up to date information needed to help in comprehending Chemistry subject matter. Therefore, professional development activities inclusive of ICT literacy skills should be enhanced.

d) Computer science

The Computer Science results concerning teaching and learning resources, as seen in Figure 106 showed that, while all the lesson plans indicated resource materials to be used during the lesson, 40% and 50% of the plans were appropriate at senior and junior levels respectively. Likewise, an average of the teaching and learning resource materials consulted were not appropriate at both senior and junior secondary levels as indicated by the 60% and 50% respectively.

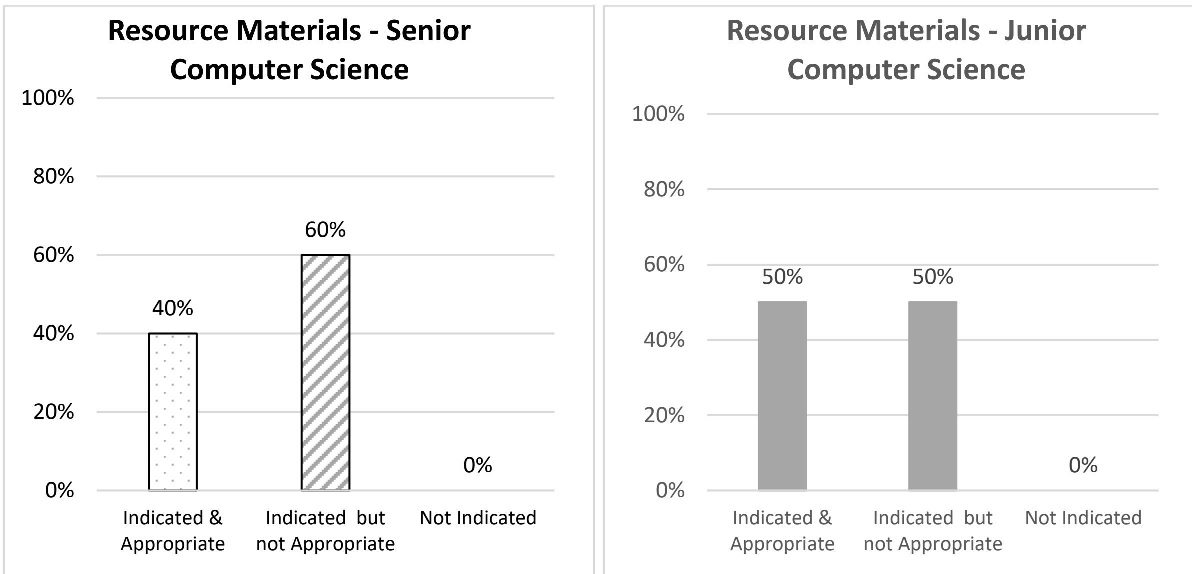


Figure 106 Resource Materials for Senior and Junior Computer Science

Since some relevant teaching and learning resources for Computer Science were forwarded to schools, the average utilization of appropriate and use of inappropriate materials might possibly imply inadequate resourcefulness in exploring relevant teaching and learning resources. This may hinder the achievement of Computer Science STEM Education Curriculum intentions. Further, the few teaching and learning resources consulted when planning for Computer Science lessons as indicated in Table18 shows that the type of resource material used were limited and that there was no consultation of e-resource materials, even in the subject of *Computer Science*.

Table 18 Resources Referred to During Senior and Junior Computer Science

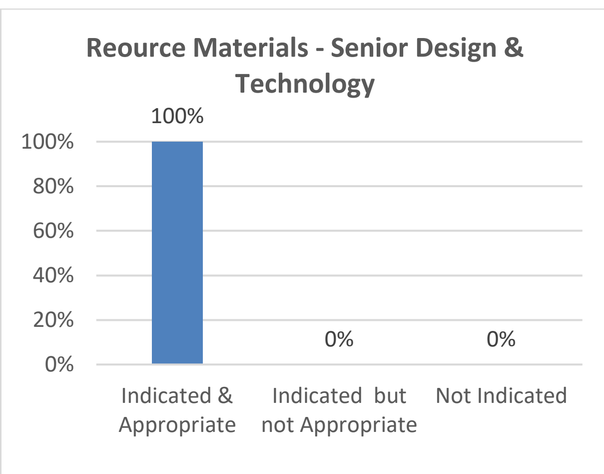
Resource Material	***Type of Resource Material***
Computer science-CS French, how computers work	Print
STEM Material, MK book 8, Basic Computer Skills book 10	Print
Gateway secondary revision	Print

Computer Science	Print

The internet can be as a source of Computer Science informative resources. The e-resources could considerably help teachers to explore various learning ideas which could be included in lesson plans. The non-utilization of e-resources may have been due to of absence of facilities, poor internet connectivity and inadequate ICT competences. The implies that teachers would not have a variety of information to help in the understanding of subject matter and also to come up with appropriate teaching and learning aids as well as construct appropriate key tasks. Further, an electronic repository needs to be developed where teachers and learners could access e-resources. Furthermore, teachers need to have in depth study of teaching and learning resources through strengthened collaboration during the lesson planning process.

e) Design and Technology

Figure 107 shows the results for teaching and learning resources referred to in the Design and Technology lesson plans as to whether they were appropriate or not. The results showed that all the teachers at senior secondary had consulted appropriate teaching and learning resources when planning their lesson in this subject. However, for the junior secondary level lessons only 33% of the lesson plans had appropriate teaching and learning resources indicated. Another 33% of the lesson plans had inappropriate teaching and learning resources indicated while the remaining 33% did not have any teaching and learning resource materials stated.



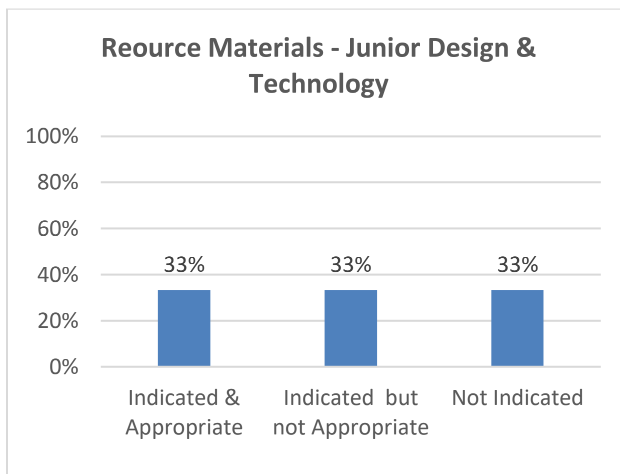


Figure 107: Resource Materials for Senior and Junior Design and Technology

The results regarding teaching and learning resources for Design and Technology showed that resource materials indicated in some cases were not appropriate for the junior level lesson plans whilst in other cases there was completely no indication of teaching and learning resources consulted during the planning stage. The cause of this could be inability to use STEM resource materials that were forwarded to the schools. Other than that, it could also have meant incapability to be resourceful in sourcing for relevant materials that could be useful in learning the concepts at hand. The implication of this could be inadequate planned content knowledge and in so doing encumbering the accomplishment of curriculum intentions. In the cases where the teaching and learning resources referred to were appropriate, it meant that teachers had good abilities that helped them select appropriate resource materials and use them to plan lessons. The implication of this would be that varied information would be taken into consideration when planning for lessons, hence the curriculum intentions would be well catered for. Conversely, despite the consulted resource materials being appropriate all of them were print and none were e-resources as shown in Table 19.

Table 19 Sample Resources referred to in Design and Technology Lessons

Teaching and learning resource	**E-Resource**
Senior Secondary Design and Technology James Garratt D&T	None
Wood Technology for Junior Certificate by Bill Gaughran et al	
Grade 9 Design and Technology Pupils' Book by J Chishala	
Machine Design by RS Khurmi and JK Gupta	
Design & Technology by C. Carbon	
MK Zambia Jack Chishala 2015, Drawing Instrument	
TD with design by A Yam-wood	
MK Design and Technology book 8, pg 25- 29	
Design and Technology book 8 / provincial common notes pamphlet	

The internet can be as a source of many educational resources for all subjects and Design and Technology is not exceptional. The e-resources could extensively help teachers to explore a wide range of explorative learning ideas which they could include in their lesson plans. The non-utilization of e-resources may have been non-existence of internet amenities, deprived internet connectivity, insufficient ICT skills. The implication of this is that teachers would have limited information to support their understanding of the subject matter. It is therefore, recommended that basic ICT literacy skills should be a component in STEM teacher capacity building training courses. Further, there is need to develop an electronic repository on the Learning Management Platform where teachers and learners could access e-resources. Furthermore, teachers need to have in depth study of teaching and learning resources through strengthened CPD activities to enhance lesson planning skills.

f) Hospitality and Tourism

The Hospitality and Tourism results as regards to the teaching and learning resources referred to during the lesson planning process are shown in Figure 108. The findings revealed that at both senior and junior secondary no teaching and learning resources were consulted during the lesson planning process as was evidently indicated.

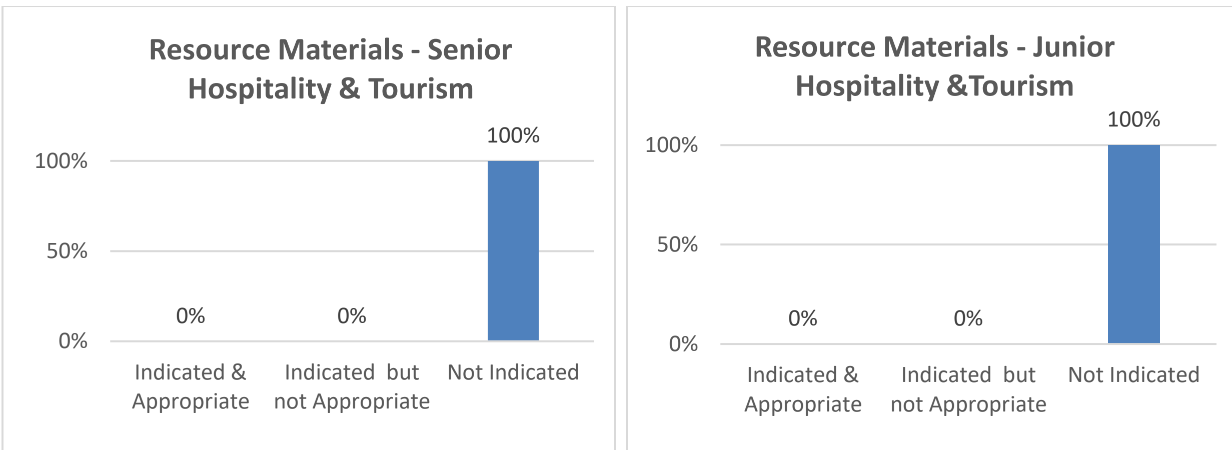
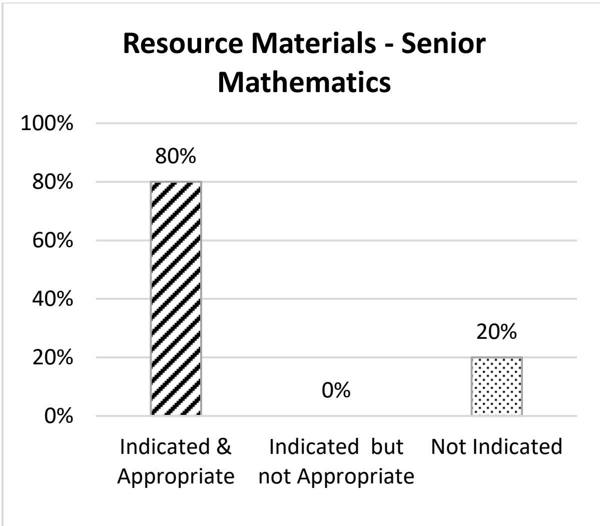


Figure 108 Resource Materials for Senior and Junior Hospitality and Tourism

The reason for not having indicated the resource materials referred to during the lesson planning process that teachers did not take this aspect with the seriousness that it deserved. This was so because they could not even indicate having referred to the STEM materials which were sent to the schools. Other than that, it could also have meant inability to be resourceful in looking for materials that could contain the topical concepts of what was being learnt. The implication of this could be limited planned information and thereby inability to attain curriculum intentions.

g) Mathematics

Regarding teaching and learning resources, the Mathematics results as seen in Figure 109 showed that 80% and 67% of the senior and junior level lesson plans had appropriate resource materials indicated on them.



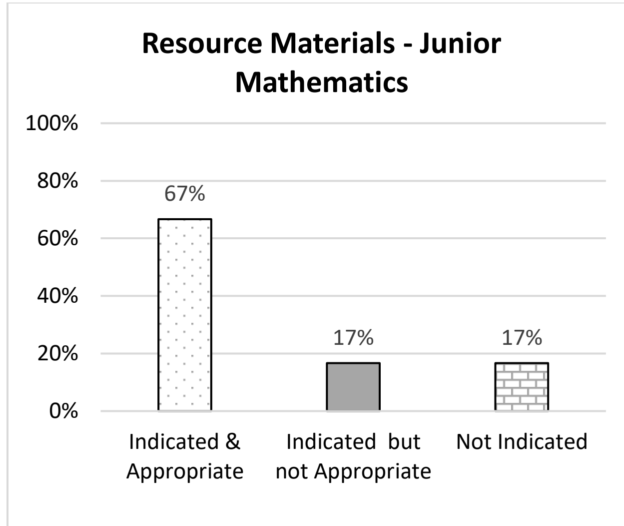


Figure 109: Resource Material for Senior and Junior Mathematics

The Mathematics results regarding teaching and learning resources, showed that at both junior and senior secondary levels Mathematics had few lesson plans that did not completely indicate the resource materials consulted during the lesson planning process. Likewise, those that indicated inappropriate resources were equally few. The 80% and 67% indication of appropriate teaching and learning resources entail that there was wide consultation of sources of information for better lesson planning. This scenario in Mathematics could mean that teachers were able to carefully select relevant resource materials in order to develop competencies and skills to help them plan lesson effectively. The insinuation of this is that the lesson plans would provide correct information that would facilitate meaningful discussions during lesson delivery. However, all the resource materials that were referred to were in print format. None of them were in electronic form, suggesting that teachers did not consult this form of resource. This is as shown in the following Table 20.

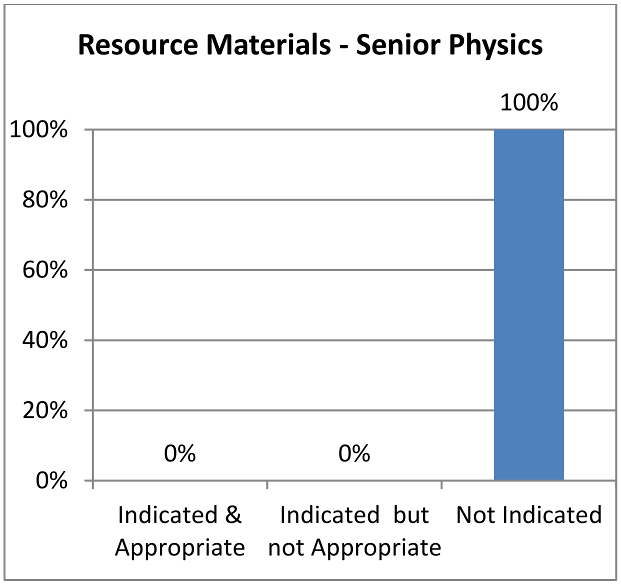
Table 20 Sample Resource Materials Consulted in Lesson Planning

Text Resource	E-Resource
Secondary School Mathematics	None
Uzbek Mathematics Pupils Book 8	
Junior Secondary Mathematics	
Golden Tips	
Zissis Pupils book	
Progress in Mathematics	
Achievers	
Grade 8 Progress in Mathematics	
Mathematics Syllabus	
Reference notes on sets in line with STEM	
Pupils book 8	
General Mathematics	

In order to help remedy this, STEM institutions are required to develop e-strategies that would incorporate training teachers in ICT skills.

h) Physics

Figure 110 shows the Physics results as regards to the teaching and learning resources. The results showed that all the lesson plans at senior secondary level did not indicate the resource materials that had been consulted during the lesson planning process. In the case of the junior lesson plans, 50% had appropriate resources indicated as having been consulted while the other 50 % had inappropriate resources indicated on the lesson plans.



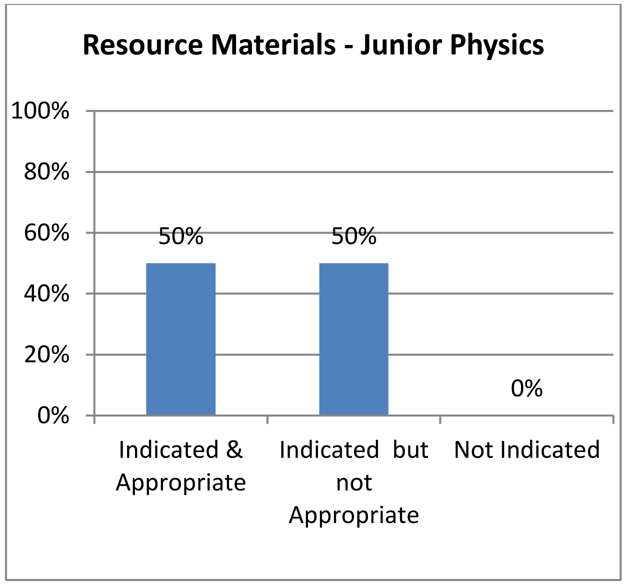


Figure 110 Resource Materials for Senior and Junior Physics

The non-indication of the teaching and learning resource materials referred to on the senior level lesson plans raises great concern. This is so because, it suggests that the teacher used their own knowledge to prepare the lessons. This could result into narrow scope of the lesson conceptualization. As for the junior lesson plans where inappropriate Physics resource materials were indicated it could mean that inappropriate or irrelevant concepts might be delivered to the learners. The other reason could have also been incapability of being resourceful in looking for relevant resource materials. This could have been as a result of not understanding what resource materials to consult. The implication of this could be limited information and ideas to be incorporated in lesson planning which would ultimately impede on the attainment of curriculum intentions. All the appropriate materials referred to were print text and none were e-resources. Despite the fact that e-resource use is a high priority in STEM Education there were still challenges that held back the wider utilization of these technologies. The reasons could include; being used to traditional use of print text, insufficient and inadequate ICT skills by teachers to consult e-resources, limited access or complete absence of internet facilities.

Summary for Planning for Teaching and Learning Resource Materials

Generally, there was more than average appropriate resource materials referred to during lesson planning. However, despite the teachers mentioning in the questionnaires that they often used e-resources, none of the resource materials consulted when planning for lessons were e-resources. The implication of this could be that teachers might have really consulted the e-resources but did not know how to reference them on the lesson plans. Further, it could imply that teachers plan the lessons hurriedly and forgot to include all the relevant information regarding references. It is therefore, recommended that teacher SBCPD activities should include ICT literacy skills and how to reference resource materials.

4.1.6. Teaching and Learning Aids Preparation

Teaching and learning aids are materials designed to help learners comprehend lesson concepts better and help in sustainable knowledge retention as well as enhance creativity. Through the utilization of teaching and learning aids the process of teaching and learning is made easier for both teachers and learners because they help to illustrate theoretical concepts. Therefore, the aids should be designed to involve learners in order to promote interaction. The many benefits of teaching aids include helping learners to acquire knowledge and enhance skills. Additionally, TLAs help teachers in illustrating or reinforcing skills or concepts, differentiating instruction and relieving anxiety or boredom by presenting information in a new and exciting way. In order to be effective, teaching and learning aids should clearly be visible, practical and conform to real size estimations or proportions. Types of teaching and learning aids include visual, audio and hands-on. It is, therefore, important for teachers to plan and prepare, well in advance before the lesson, the teaching and learning aids that would be used in the during lesson delivery. As the teachers plan for the teaching and learning aids, they should clearly indicate who should prepare, who should use, at what stage of the lesson the aids would be used and indicate what its purpose is. If the aids are to be used for the whole class, they should be big enough for everyone to see. In the preparation of teaching and learning aids safety precautions (learning environment) should be strictly considered to avoid accidents.

In this context, teaching and learning aids preparation assessed if the lesson plans indicated preparation of materials to be used by the teacher, the learners or both in the implementation of the lesson. The results for teaching and learning aids across subjects and grades were as shown:

a) Agricultural Science

Figure 111 shows the indication of teaching aids on Agricultural Science lesson plans. The results show that all the lesson plans indicated the teaching and learning aids that would be used during the lesson. Further, 50% of the plans indicated who would use the teaching and learning aids. In other words, 50% were to be learning aids. The other 50% did not indicate who would use these aids.

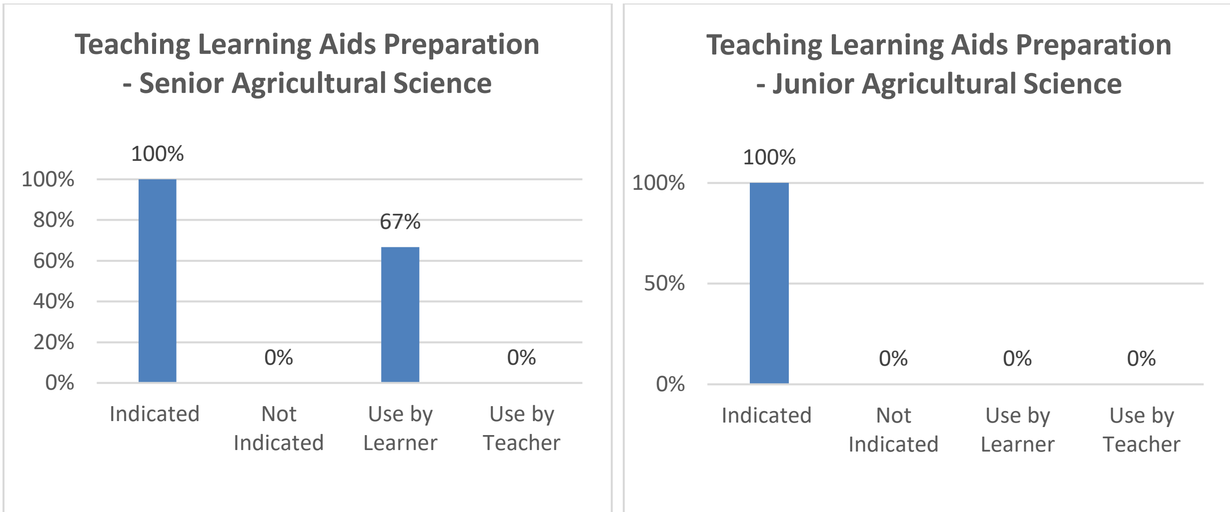
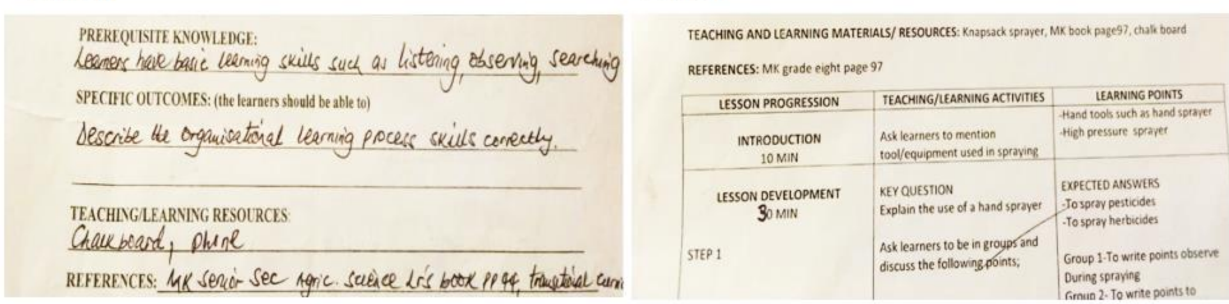


Figure 111 Teaching Learning Materials for Senior and Junior Agricultural Science

The indication of teaching and learning aids on the Agricultural Science lesson plans was commendable as can be seen in the graphs. In STEM Education learners need to be at the centre of learning. It was anticipated that the learning aids would help support active learning which would ultimately lead to development of expected knowledge and competencies. However, analysis of the kinds of teaching and learning aids indicated reveals that there appears to be a mix-up between an aid and a resource. This is so because most of the lesson plans combined the teaching and learning aids with resource materials. Cases in point are shown in the illustration in Figure 112 below.

Case A

Case B



PREREQUISITE KNOWLEDGE: Learners have basic learning skills such as listening, observing, searching

SPECIFIC OUTCOMES: (the learners should be able to)

Describe the organizational learning process skills correctly.

TEACHING/LEARNING RESOURCES: Chalk board, phone

REFERENCES: MK Senior Sec Agric. Science Lr's book pp 94, transitional curri

TEACHING AND LEARNING MATERIALS/ RESOURCES: Knapsack sprayer, MK book page97, chalk board

REFERENCES: MK grade eight page 97

LESSON PROGRESSION	TEACHING/LEARNING ACTIVITIES	LEARNING POINTS
INTRODUCTION 10 MIN	Ask learners to mention tool/equipment used in spraying	-Hand tools such as hand sprayer -High pressure sprayer
LESSON DEVELOPMENT 30 MIN	KEY QUESTION Explain the use of a hand sprayer	EXPECTED ANSWERS -To spray pesticides -To spray herbicides
STEP 1	Ask learners to be in groups and discuss the following points;	Group 1-To write points observe During spraying Group 2- To write points to

Figure 112: Indication of Teaching and Learning Aids

The non-indication, at junior level, of who was to use the teaching and learning aids might result in disorganized use or no use at all during lesson implementation. This may render the teaching and learning aid(s) useless and might dampen the learners' morale. To alleviate the non-preparation of teaching and learning aids, teachers need to be encouraged to be resourceful through conducting intensive study of teaching and learning materials during lesson planning if curriculum intentions are to be met.

b) Biology

For the Biology lesson plans as seen in Figure 113 both at senior and junior levels all the lessons did indicate teaching and learning aids as prepared for the lesson. The results further show that 33% of lesson plans at senior level and 50% at junior level indicated that these aids would be used by learners and teachers respectively. This implies that 67% of the lesson plans at senior and 50% at junior level did not indicate who would use the aids during the lesson.

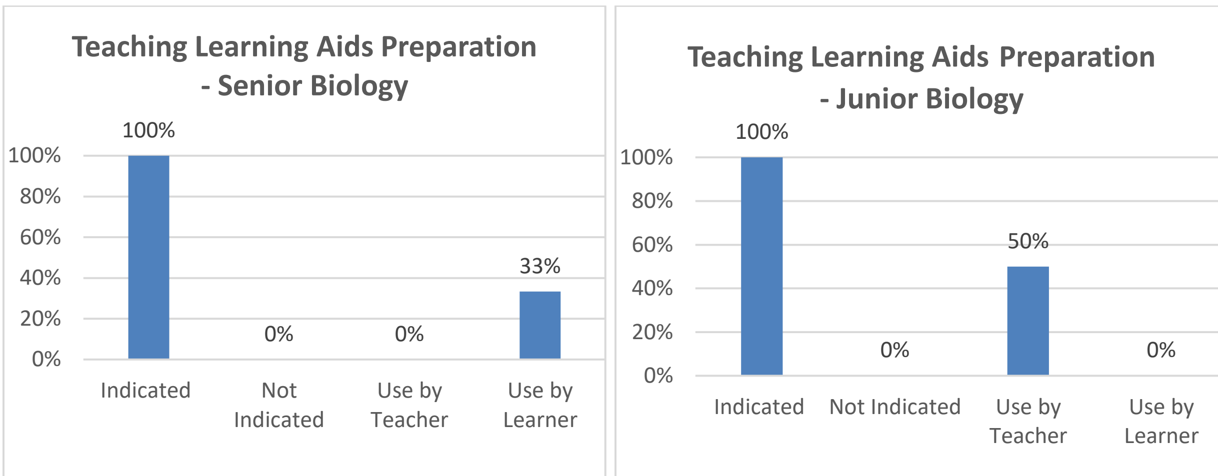


Figure 113: Teaching and Learning Materials Preparation Senior and Junior Biology

The purpose of planning and preparing teaching and learning materials in Biology is to encourage active learning, development of different skills, desirable values and attitudes in learners. The fact that teaching and learning aids were indicated on the lesson plans was not adequate in itself if the users were not clearly stated. Therefore, the mere listing of teaching and learning aids on the lesson plan could simply mean filling in the blanks because the lesson plan template dictates such. The reason for this could be that the teachers may have thought that since learners should be at the centre of learning in STEM Education there was no need to plan for physical objects. The implication of the 50% indication that the aids would be used by the teacher entails that the teacher would use it for demonstration only and that there were no plans for the learners to manipulate the aids. In STEM Education learners need to be at the centre of learning. In order to remedy this, intensive study of teaching and learning materials when planning for lessons in STEM education cannot be understated if curriculum intentions have to be realised.

c) Chemistry

Figure 114 shows the results of teaching and learning aids indication on Chemistry lesson plans. The findings as seen at both senior and junior levels reveal that all the lesson plans had teaching and learning aids indicated on them. Further, it was observed that 25% of the lesson plans at senior level indicated that the aids would be used by the learners while at junior level it was not indicated who would use the aids.

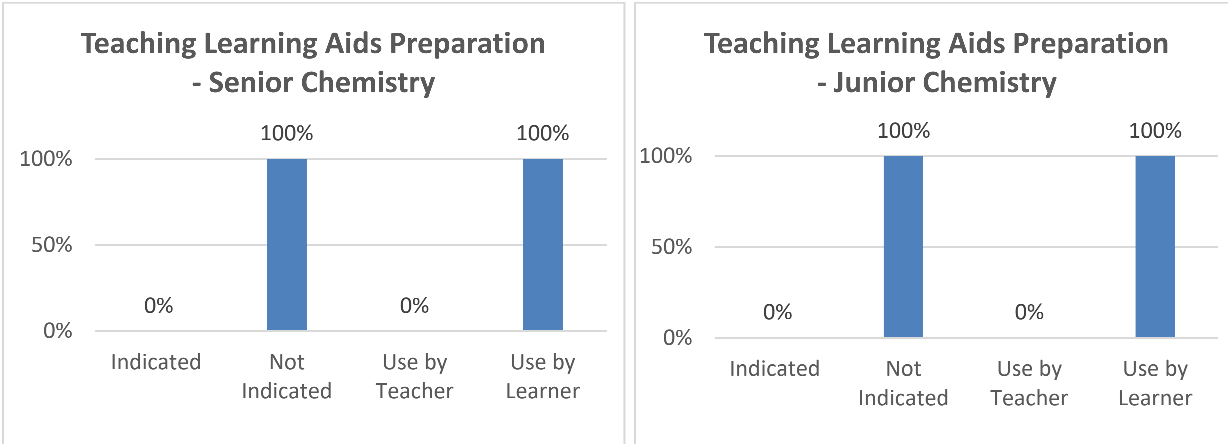


Figure 114 Teaching Learning Materials Preparation - Senior and Junior Chemistry

While it was indicated on all the lesson plans that teaching and learning aids would be used, there was no indication on who would use, how they would be used and at what stage during the lesson. This tendency might result in skipping the use of the aid or introduction of the aid at a wrong time. It might also result in loss of relevance and purpose. The quantity of the aids, if not stipulated, could equally be compromised and could affect the learning process.

d) Computer Science

The results for the Computer Science teaching and learning aids indicated on the lesson plans are shown in Figure 115. The findings disclosed that the teaching and learning aids were indicated at both senior and junior level lesson plans. However, only the senior lesson plans had indicated that the aids would be used by the learners (80%) while no at junior level there was no indication of who the target was, and at what stage the aids would be used.

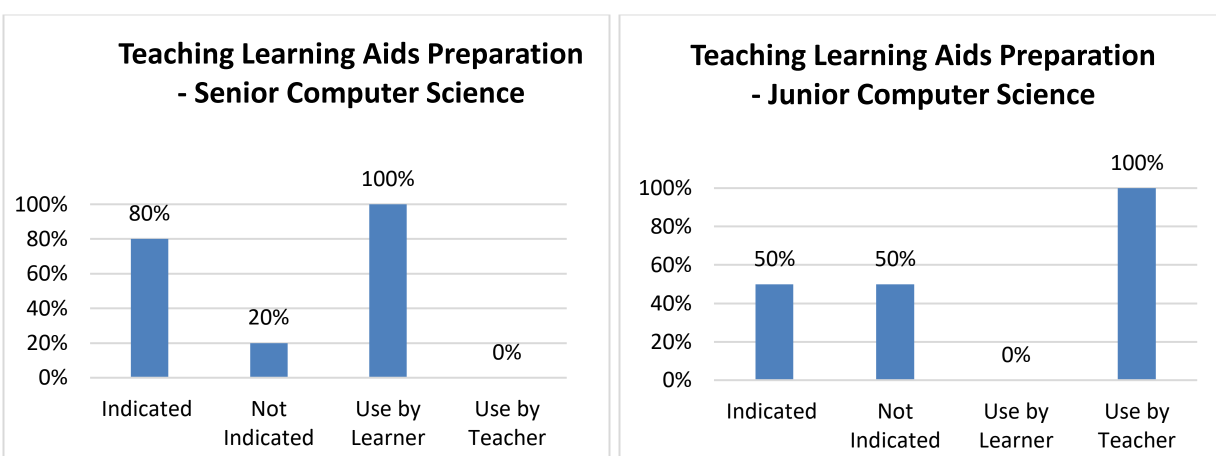


Figure 115: Teaching Learning Materials Preparation for Senior and Junior Computer Science

In Computer Science, like any other STEM subject, hands-on activities should carry the order of the day during the lesson process. Therefore, it is imperative that learners are allowed to interact with the aids in order for them to construct their own knowledge. As regards to the usage of teaching and learning aids it was indicated that at senior the aids would be used by learners. This was evidenced by the constructivist nature of lesson activities that were planned for. The reason for this could have been that there was understanding of computer science STEM Education Curriculum intentions. These plans suggest that learners would be engaged in explorative activities that would ultimately lead to attainment of desired knowledge and competences. At junior level, the implication of not indicating who would use the aids, and for what purpose, might result in continued teacher centeredness which impedes the development of skills needed in modern day society as the aids might be planned to be used for demonstration purpose only. Therefore, to remedy this, CPD activities must be enhanced.

e) Design and Technology

Figure 116 shows results of Design and Technology teaching and learning aids indicated on the lesson plans. The findings as seen at both senior and junior levels reveal that all the lesson plans had teaching and learning aids indicated on them. Further, it was observed that 50% of the lesson plans at junior level indicated that the aids would be used by the learners while at senior level it was not indicated who would use the aids.

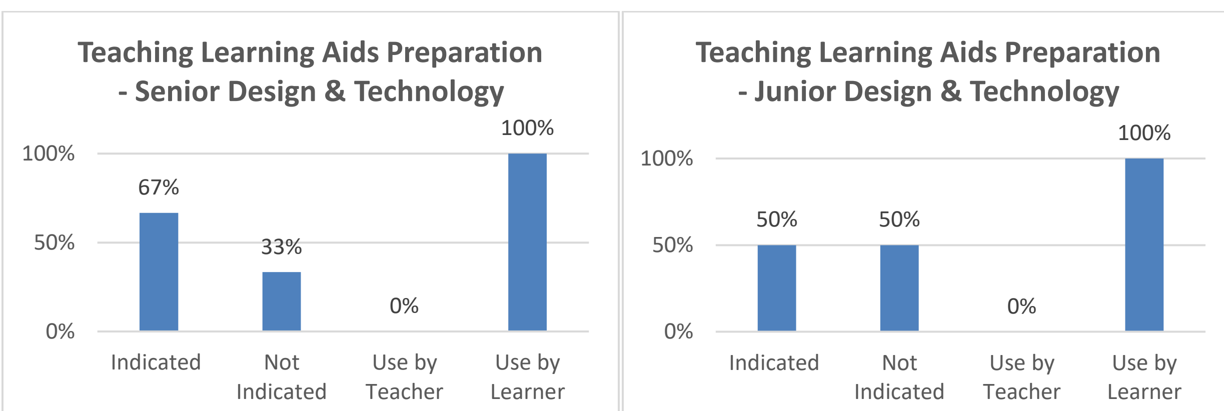


Figure 116: Teaching Learning Materials Preparation - Senior and Junior Design and Technology

Although it was indicated on all the lesson plans that teaching and learning aids would be used, only 50% of lesson plans at junior level indicated who would use but not how they would be used and at what stage during the lesson. This predisposition might result in not using the aid or it being introduced at a wrong time. Consequently, the importance and purpose of the teaching and learning aid might be lost altogether.

f) Hospitality and Tourism

Figure 117 shows results of Hospitality and Tourism teaching and learning aids indicated on the lesson plans. The findings indicate that at senior all the lesson plans had teaching and learning aids indicated on them. However, it was observed that none of the lesson plans had indicated teaching and learning aids at junior level.

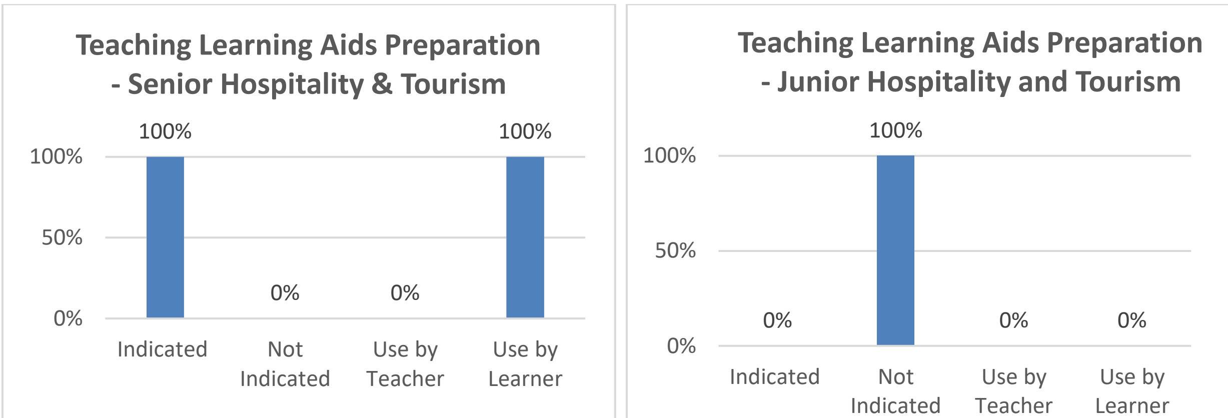


Figure 117: Teaching Leaning Material Preparation - Senior and Junior Hospitality & Tourism

On one hand, even though the teaching and learning aids were indicated on the senior lesson plans who, how and when to use them was not stated. On the other hand, no indication and use, whatsoever, of the teaching and learning aids were shown on the junior lesson plans. The consequence of this might be that the aid could not be used or may be introduced at a wrong time. This may render the aid irrelevant and useless.

g) Mathematics

The results for indication of teaching and learning aids on Mathematics lesson plans are shown in Figure 118. The findings disclose that at both senior and junior levels all the lesson plans had teaching and learning aids indicated on them. Further, it was observed that 40% of the lesson plans at senior level indicated that the aids would be used by the learners while at junior level it was not indicated who would use the aids.

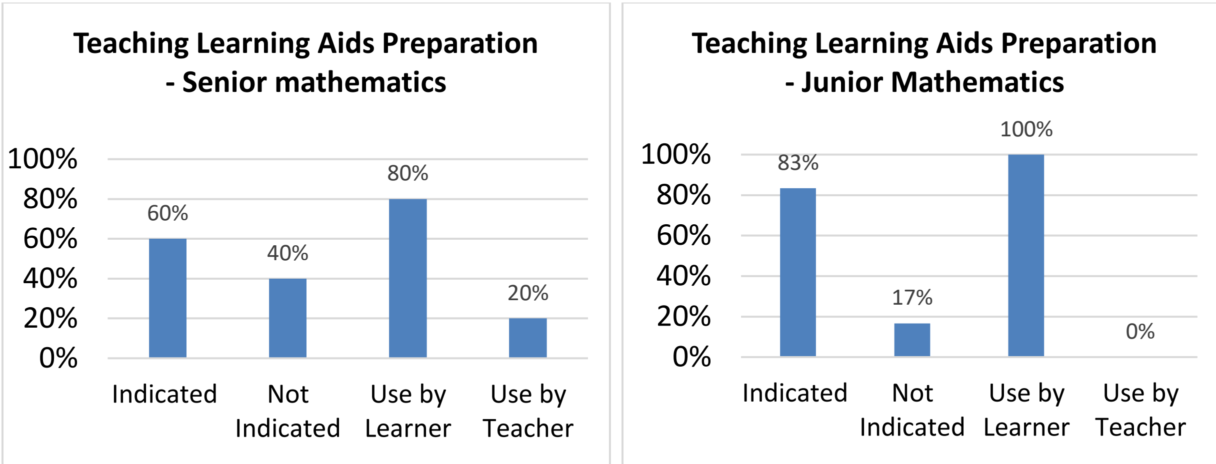


Figure 118: Teaching Learning Aids Preparation - Senior and Junior Mathematics

Despite the fact that it was indicated on all the lesson plans that teaching and learning aids would be used, only 40% of lesson plans at senior level stated who would use them but not how and when they would be used during the lesson. Teachers should, therefore, be encouraged to state in detail what kind of teaching aid, for what purpose and how it would be utilised by either them or learners. Further, CPD activities, including Lesson Study, should be used for such competencies and skills in order for teachers to improve their pedagogical content knowledge.

h) Physics

For the Physics lesson plans as seen in Figure 119, no teaching and learning aids were indicated for the lessons at senior secondary level whilst at junior secondary level 75% of the lesson plans indicated teaching and learning aids and that these would be used by the learners. There was no information regarding teaching and learning aids on 25% of the lesson plans at junior level.

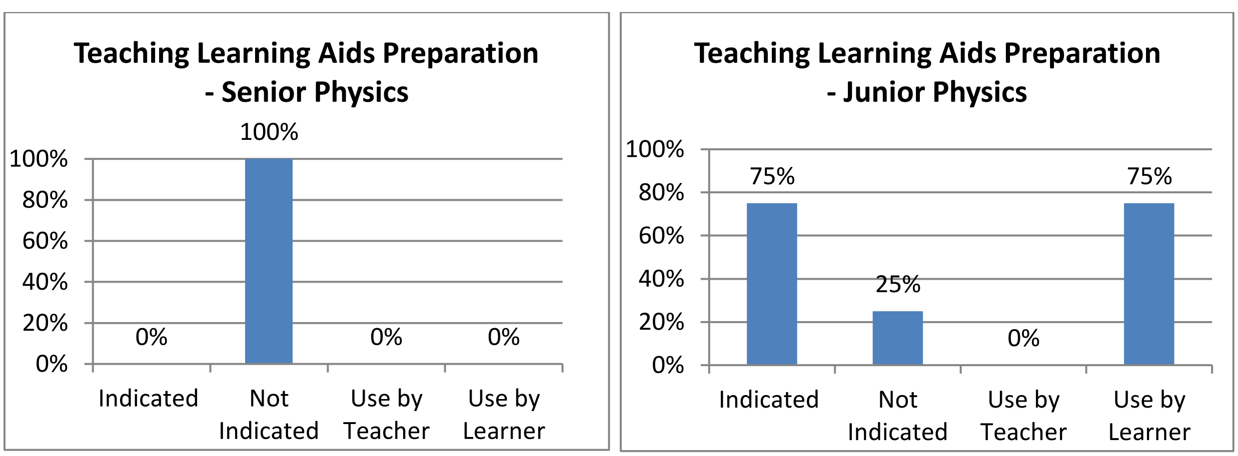


Figure 119: Teaching Learning Materials Preparation for Senior & Junior Physics

The none indication of teaching and learning aids on lesson plans at senior level could imply that there would be inability to foster desired knowledge and skills in the learning process as mostly rote learning will characterize lessons without teaching and learning aids. The above average indication (75%) of teaching and learning aids on the junior level lesson plans and the fact that learners were targeted to use them could be as a result of the teachers' understanding that in STEM Education, learners need to be at the centre of learning. The implication of this was that the learning aids would help support active learning which would eventually lead to development of anticipated knowledge and competencies. However, the teaching and learning aids indicated to be used were all conventional. Cases in point amongst others include: "*measuring cylinders, rulers, rectangular glass blocks, tiny threads, standard masses and water*" to learn the concept of volume and "*metre rule, exercise book, pencil, chalk board and mathematical set*" to learn the concept of length. It would have been better to also include aids that would help provoke critical thinking, creativity and innovativeness. Therefore, there is need for more capacity building, at various fora, on the importance of teaching and learning aids.

Summary on Planning for Teaching and Learning Aids

Figure 120 shows summary results of planning for teaching and learning aids, for all the STEM subjects at both senior and junior levels, obtained from the lesson plans. The findings indicated that the lesson plans at both senior and junior levels had impressive indication of the teaching and learning aids at 88% and 84% respectively. However, there was very low clarification on who would use the indicated teaching and learning aids at both senior and junior levels. At senior level, out of the 88% lesson plans which indicated teaching and learning aids, 8% showed that these aids would be used by the teachers and 22% showed that the aids would be used by the learners. At junior level, of the 84% lesson plans which indicated teaching and learning aids, 6% showed that the aids would be used by the teachers and 16% specified that they would be used by the learners.

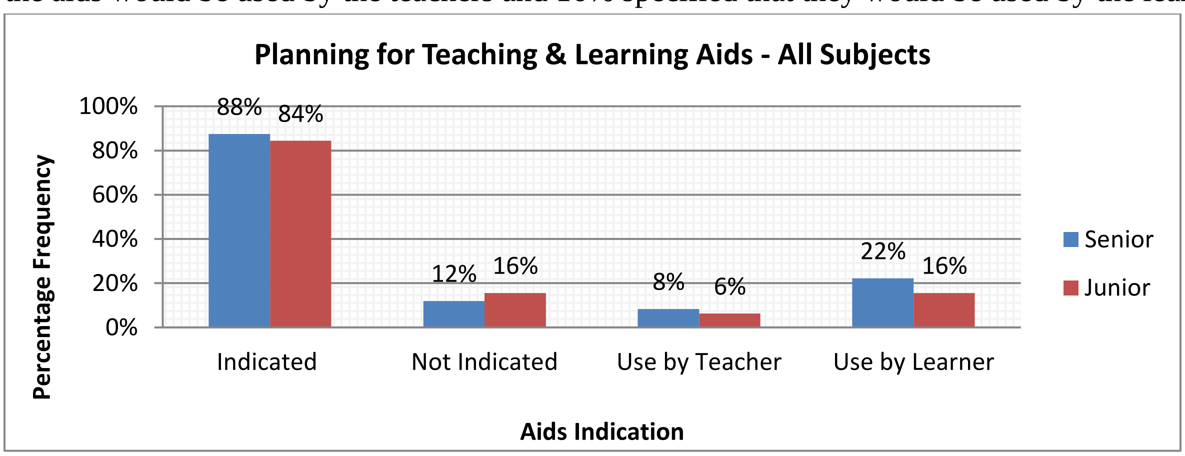


Figure 120: Planning for Teaching & Learning Aids - All Subjects

The indication of teaching and learning aids on the lesson plans at both junior (84%) and senior (88%) levels was a positive stride which should be encouraged. Nonetheless, the low indication, at both junior and senior levels, on who should use the teaching and learning aids is a serious source of concern in STEM Education. It is important to clarify who is supposed to use the teaching and learning aids during planning for lessons. Teachers may need to use teaching and learning aids for demonstration and to reinforce learning. The use of Teaching and learning aids by learners widens the scope of understanding the concepts. Further, TLAs help teachers in illustrating or reinforcing skills or concepts. The implication of planning for TLAs is that it would lead to fostering acquisition of desired skills and competencies in learners during lesson delivery. Non-indication of the targeted user may imply non-creativity on the part of the teacher. Nicholson wrote, "*In any environment, both the degree of inventiveness and creativity, and the possibility of discovery, are directly proportional to the number and kind of variables in it" (1972, 6).* Therefore, expanding learner's access to non-conventional STEM materials can serve to provide a wider range of learning opportunities in the classroom. To be more effective teaching and learning aids in STEM education need to be context specific so that they are meaningful to everyday life of the learners. There is need for teachers to prepare teaching and learning aids that would nurture the development of knowledge, skills and positive values. To do this, during lesson planning; there is need to intensively study the teaching and learning materials. This could be done individually and collaboratively as well as through enhanced professional development activities. It is therefore recommended that teachers be involved in intensive study of teaching and learning materials so that appropriate TLAs are planned for and prepared.

STEM Education - Curriculum Delivery

As discussed in Chapter 2, assessment of learning in STEM Education follows the frame of planning, delivery and learner progression (See Figure 1). Having presented and discussed the findings on planning in STEM Education, this section focuses on the implementation of the STEM Curriculum. Curriculum delivery carries with it the intentions and the teacher's understanding as well as strategies planned for its implementation. Since implementation takes place through the interaction of the learner and the planned learning opportunities, the role and influence of the teacher in the process is indisputable. To this effect, it is important that teachers interpret and put into practice curriculum prescribed intentions correctly in order to help learners acquire the necessary knowledge, skills and competencies. The intentions of the Transitional STEM Curricula needed to be implemented correctly. To this effect, the findings on curriculum delivery in this research included aspects of lesson implementation through lesson introduction, development, conclusion and utilization of teaching and learning aids.

4.1.7. Lesson Delivery

The component of lesson delivery is closely related to lesson preparation. Delivery of lesson is putting into effect what was planned for the lesson in terms of content, pedagogy as well as teaching and learning materials. In lesson delivery curriculum intentions are interpreted through the interaction of teacher, learners as well as teaching and learning aids. The focus during delivery of lessons in this context was how the introduction, development and conclusion of the lessons were done. Additionally, focus was also on how the teaching and learning aids provided enhance learning.

4.1.7.1. Lesson Introduction

Lesson introduction is a vital aspect of classroom instruction. It sets the tone of lessons through provision of interest and motivation by allowing learners to think hypothetically on tasks at hand. Beginning of a lesson introduces learners to what the expectations may be and provides an opportunity for them to visualize the content and direction in order to get everyone ready. Being the entry point into a lesson, introduction must be planned for very carefully so that it captures the attention of all the learners and make them look forward to learning. In STEM Education constructivism approach is advocated in which the introduction could be by way of providing appropriate and related key tasks (scenario, problem statement and key question) which would prompt learners to get into an activity either individually or in groups. The construct of lesson introductions has been operationalized and defined using different variables In this research introduction of lessons took into consideration key tasks presented, how they engaged the learners as well as whether they were initially planned for. The lesson introduction results and analysis across subjects and grades were:

a) *Agricultural Science*

Figures 121 and 122 show results on lesson introductory aspects observed during the implementation of the Agricultural Science lessons at senior and junior levels respectively.

At senior level the findings revealed that the total average score in problem statement was 50% at planning stage as compared to 33% at implementation stage representing 17 percentage point decrease. Contrariwise, the ordinary questions average score was 50% at planning and 67% at implementation representing 16 percentage point increase. In terms of scenarios and key questions none were presented at both planning and implementation stages.

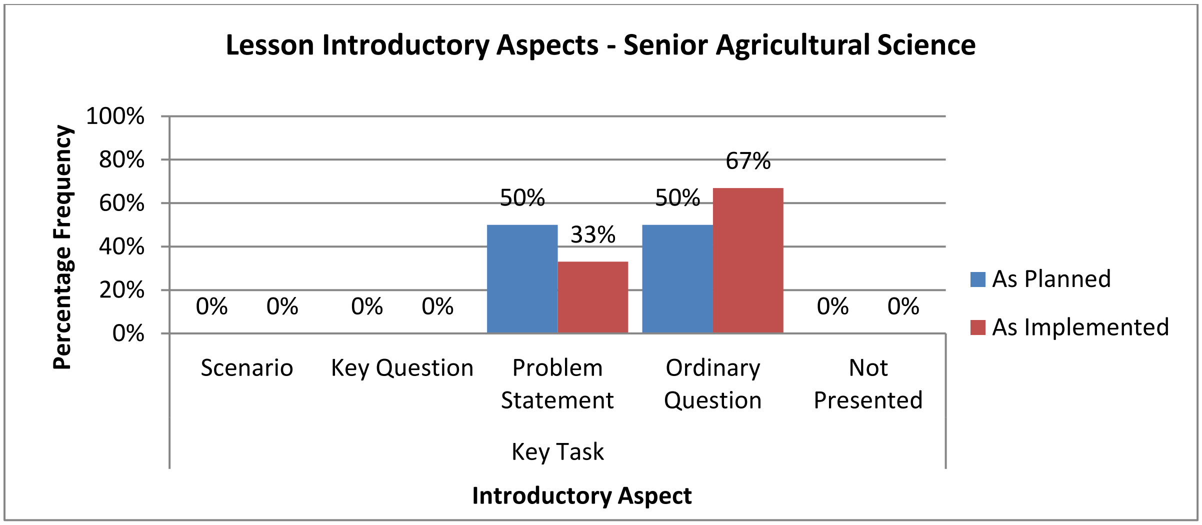


Figure 121: Lesson Introductory Aspects - Senior Agricultural Science

For the junior level, the introductory tasks implemented were all ordinary questions as they had been planned while the key tasks were neither planned nor implemented.

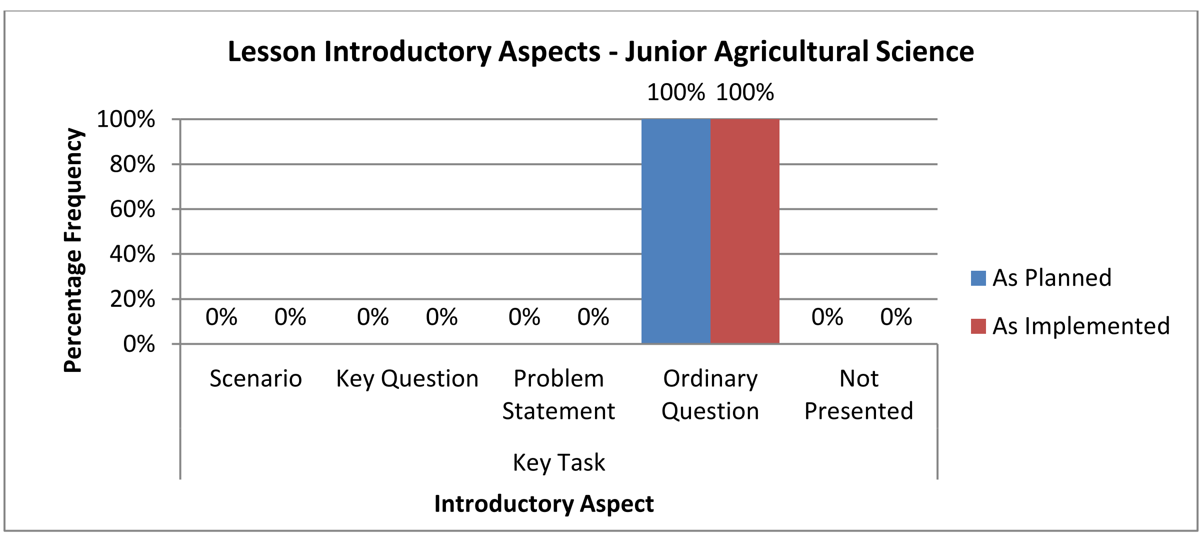


Figure 122: Lesson Introductory Aspects - Junior Agricultural Science

From the lessons observed that some key introductory aspects were not planned and subsequently executed. Consequently, not completely using key task might imply that teachers had limited knowledge and tact on how to execute the introductory lesson activities as envisioned in STEM Education. This could lead to some learners not getting what they ought to as their teachers may not be motivating them enough in the way lessons were introduced. In STEM Education learners are supposed to be active participants therefore, they need to be appropriately engaged right from the beginning of the lesson. This is in order for them to re-align their minds to what is to be learnt as well as create opportunities for them to think and apply new ideas. Additionally, the senior level results showed an attempt in the use of problem statement, however, there was a disparity in the plans and implementation. This could suggest that there were inadequate pedagogical skills needed to put into effect the planned lesson introductory activities. If learners are not motivated enough effective learning will not take place thereby, making learners not to fully engage towards achieving the lessons' intended outcomes. Further, the absence of key tasks at junior level both at planning and implementation stages implies that, there was still influence of positivism as the teachers planned and implemented their lessons as was observed by the use of ordinary questions. The use of ordinary questions may not bring out the desired learner attributes such as critical, creative and analytical thinking. It is therefore, recommended that schools should strengthen SBCPD activities where teachers would be capacity built in the formulation of appropriate introductory activities. Such activities can also be reinforced during tailor-made training workshops at all levels. There is need to document the good practices, in form of video, audio or texts exhibited by other teachers and share them with those who are facing challenges in introducing lessons.

b) Biology

The results in Figure 123 and 124 show Biology lesson introductory aspects at senior and junior respectively.

The findings at senior level revealed that there were less than average plans and use of scenarios (33%) as introductory activities. In terms of ordinary questions, there was a 34% decrease from the planned 67% to the 33% utilized.

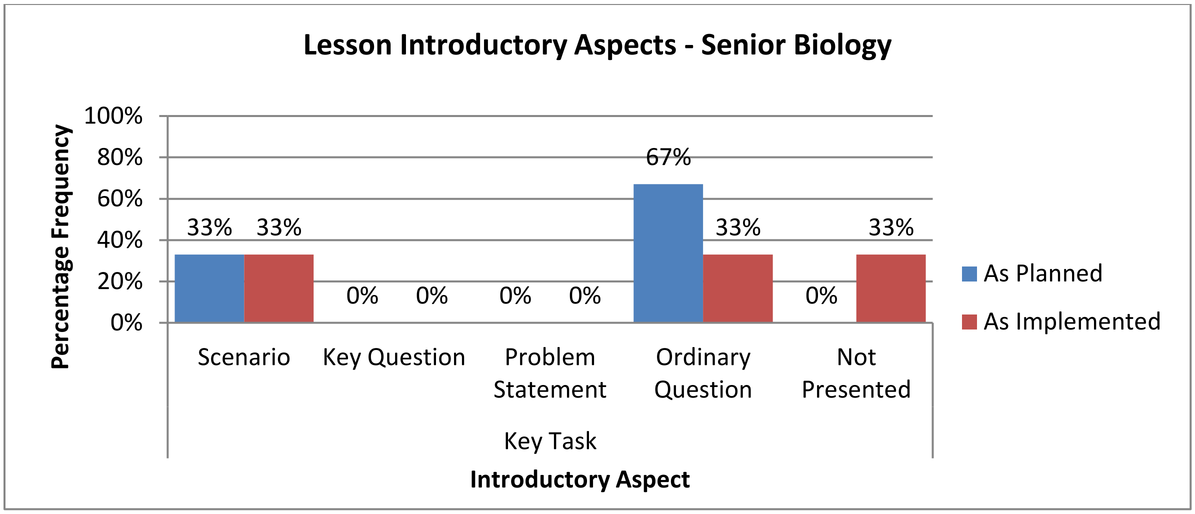


Figure 123: Introduction & Key Questions in Senior Biology

At junior level there was average indication of ordinary questions on lesson plans and their use in lesson delivery. In terms of key tasks 50% of the lesson plans indicated key questions to be used but these were not executed in the lessons. Likewise, the scenarios executed in the lessons were not indicated on the lesson plans.

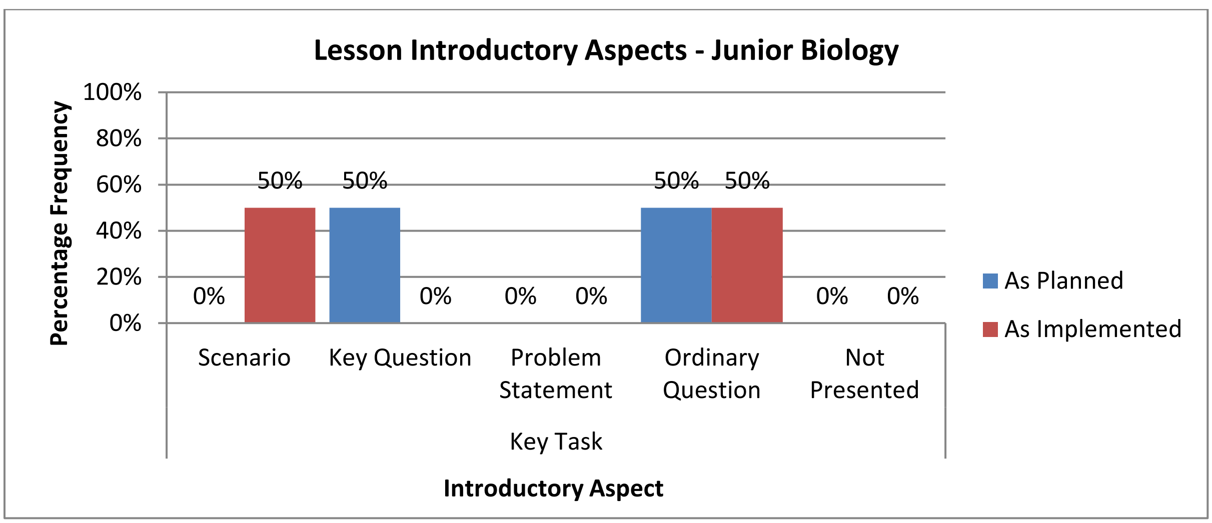


Figure 124: Introduction & Key Questions in Junior Biology

One hand, the below average and average indication as well as execution of key tasks at senior and junior levels respectively might have been as a result of STEM teachers not having adequate knowledge and competencies on how to craft and implement the recommended introductory key tasks. This is illustrated in Figure 125 where an ordinary question was posed as key task.

Figure 125: Sample Introductory Key Task - Senior Biology

The task presented in Figure 125 would only prompt recalling basic information about cells as was observed from the learners' responses on the far right of the figure. Such type of lesson introductory tasks might not provoke learners to think critically, creatively and analytically in order to develop problem-solving skills. On the other hand, not implementing what was indicated on the lesson plans while implementing that which was not planned may mean that teachers failed to relate planning to the implementation process. They treated the two (planning and implementation) as discrete aspects which should not be the case in STEM Education as seen in Figure 1 that should always be a refluxing relationship among the three facets.

Learners become keen to learn whenever they get the motivation to do so at the beginning of the lesson. It is here that the teachers should ensure to capture the learners' minds before they could start wondering away from what would be intended for them. To this effect, teachers need to be adequately trained so that they could enhance their PCK as regards to lesson introductory aspects.

c) Chemistry.

Figures 126 and 127 show results for Chemistry lesson introductory aspects observed at both senior and junior levels respectively.

At senior level, the findings disclosed that there were disparities in what was planned and executed. None of the lesson plans had scenarios planned but 25 % of lessons used them during implementation. Likewise, 25 % of problem statements were planned and 50 % of the lessons had problem statements presented. Further, a decrease of 50 % in terms of ordinary questions was observed as 25 % of the lessons used them as opposed to the 75 % that was initially planned.

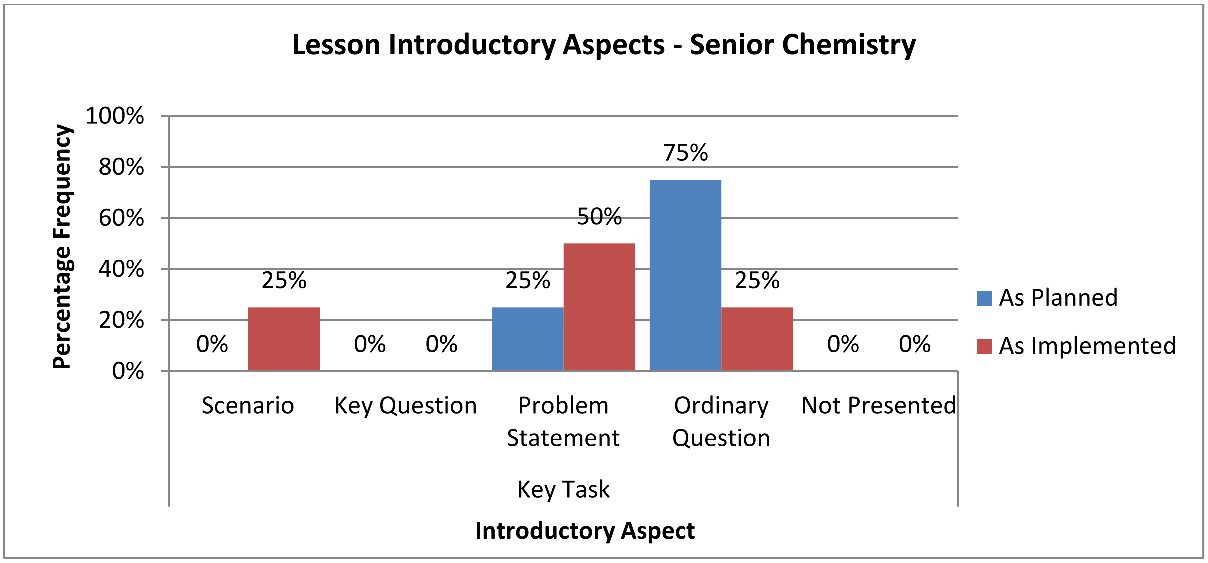


Figure 126: Lesson Introductory Aspects - Senior Chemistry

At junior level, despite the efforts to collaborate at planning stage as seen in Figure 127, none of the lessons observed used recommended key tasks. All the introductory tasks were in form of ordinary questions both planned and implemented as shown in Figure 127.

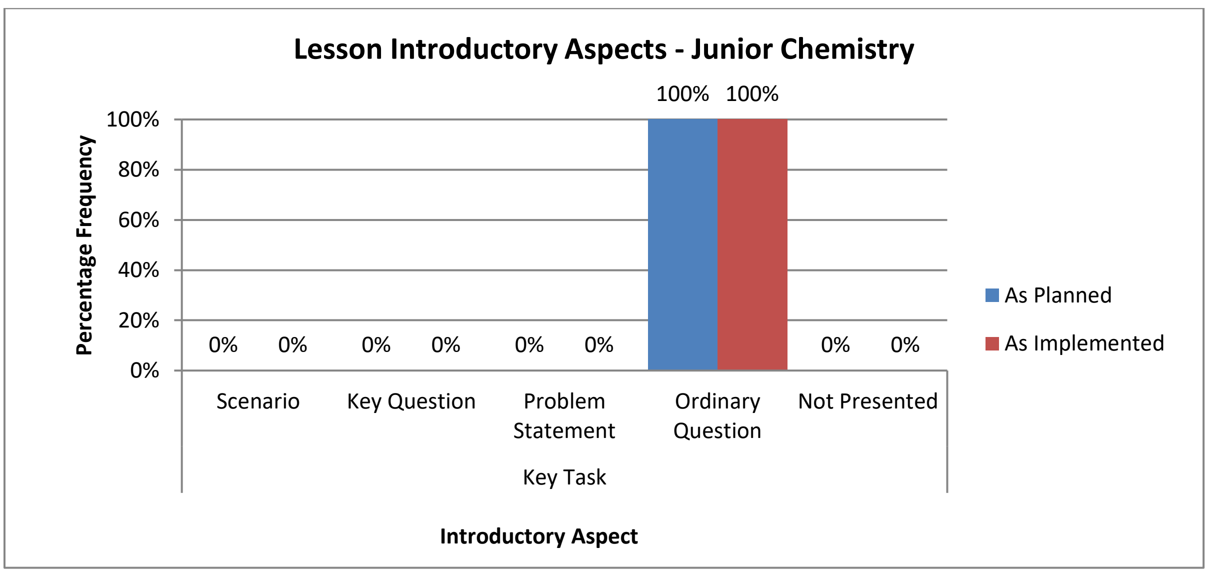


Figure 127: Lesson Introductory Aspects - Junior Chemistry

The disparities between what was planned and implemented entails that there was inadequate correlation regarding planned and implemented introductory activities. The reason for this might be that teachers did not devote adequate time to the lesson planning process. The detachment of the planning from the implementation process raises concern as it may entail that the introductory activities were impulsively thought of. Therefore, they may not have the ability to sustain the learners' enthusiasm throughout the lesson. Figure 128 is a caption showing a case in which there was disparity between the planned and implemented introductory aspects.

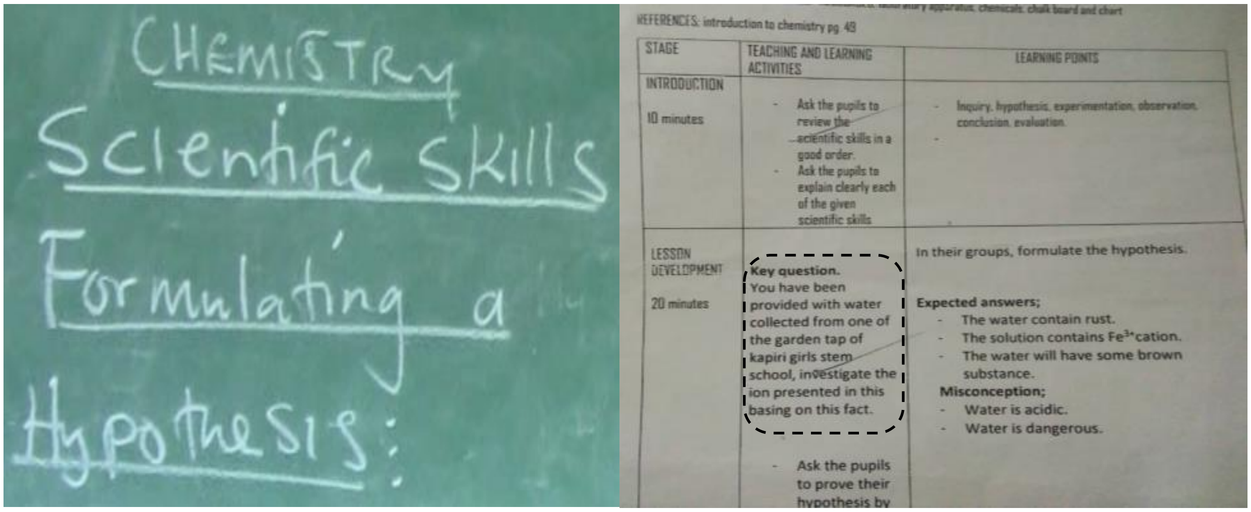


Figure 128: Sample Introductory Key Aspect Senior Chemistry

From the caption in Figure 128, the presented introductory task on the left is not the one that was planned for as shown in the encircled area on the right. Additionally, the key task was not appropriately formulated and presented as it neither focused nor addressed both the curriculum and lesson intentions. For effective teaching and learning to take place, there should be a continuous linkage between the planning for lessons and lesson delivery.

Further, at junior level, it was observed that all the lessons planned and used ordinary questions as lesson introductory aspects. The reason for this might have been that teachers were still being influenced by the positivist way of teaching and learning. The use of ordinary questions may not bring out the desired learner attributes such as critical, creative and analytical thinking. It is therefore, recommended that schools should strengthen SBCPD activities where teachers would be capacity built in the formulation of appropriate introductory activities. Such activities can also be reinforced during tailor-made training workshops at all levels.

d) Computer Science

Figures 129 and 130 indicate results of lesson introductory aspects in Computer Science at senior and junior levels respectively.

At senior level the findings show that lesson plans had indicated 60% scenarios, 20% key questions and 20% ordinary questions. However, at implementation stage scenarios decreased to 40%, key questions reduced to 0% while ordinary questions increased to 40%.

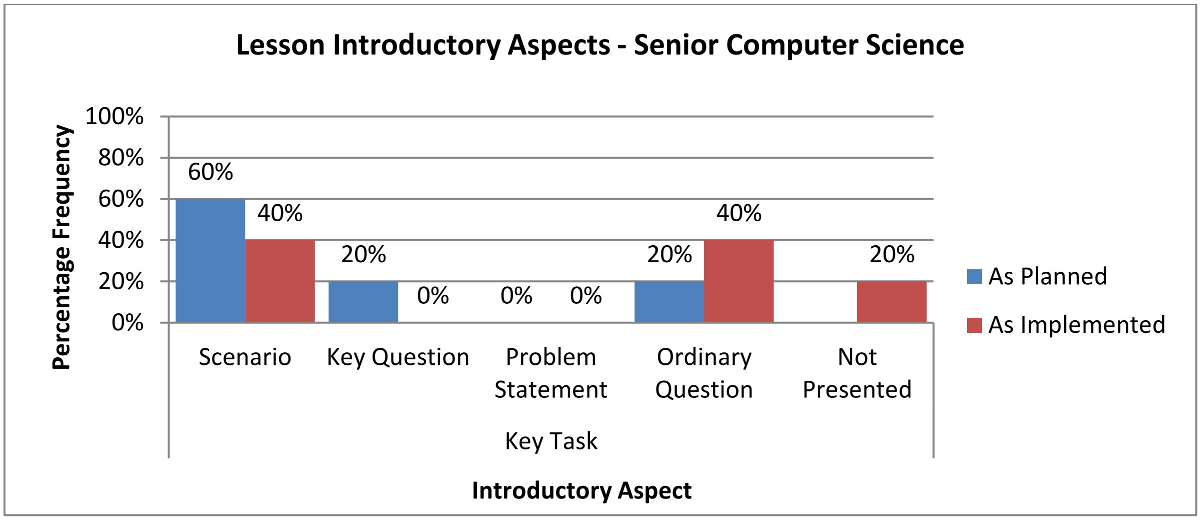


Figure 129: Lesson Introductory Aspects - Senior Computer Science

At junior level, 50% of the lesson plans had indicated scenarios and 50% ordinary questions as introductory activities. There was no indication of either key questions or problem statements at the planning stage. During lesson implementation, however, there was increase in percentage of the scenarios presented to 100% while no ordinary question was posed at all.

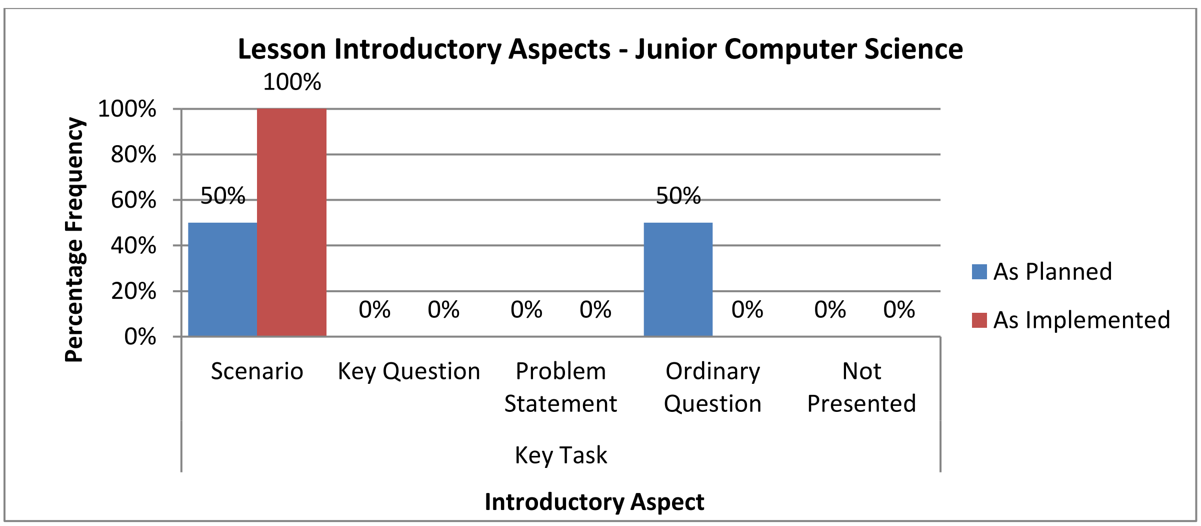


Figure 130: Lesson Introductory Aspects - Junior Computer Science

The inconsistencies seen in the planned introductory aspects and the implemented ones may be as a result of STEM teachers not being able to connect planning to delivery. The departure from what was initially planned to other strategies at implementation stage clearly shows the gap between what is intended and what actually gets delivered to learners. Such disparities might lead to distortions in the intentions of the Curriculum as learners may not be able to attain the aspirations espoused. Arising from this, there is need to incorporate lesson planning and delivery aspects in CPD activities at all levels.

e) Design & Technology

Figures 131 and 132 show results on lesson introductory aspects observed during the implementation of the Design and Technology lessons at senior and junior levels respectively.

At senior level the findings revealed that the total average score in scenario was 25% at planning stage as compared to 50% at implementation stage representing 25 percentage point increase. Contrariwise, the ordinary questions average score was 75% at planning and 25% at implementation representing 50 percentage points decrease. None of the lesson plans had problem statement planned but 25 % of lessons used them during implementation. Key questions were not presented at both planning and implementation stages.

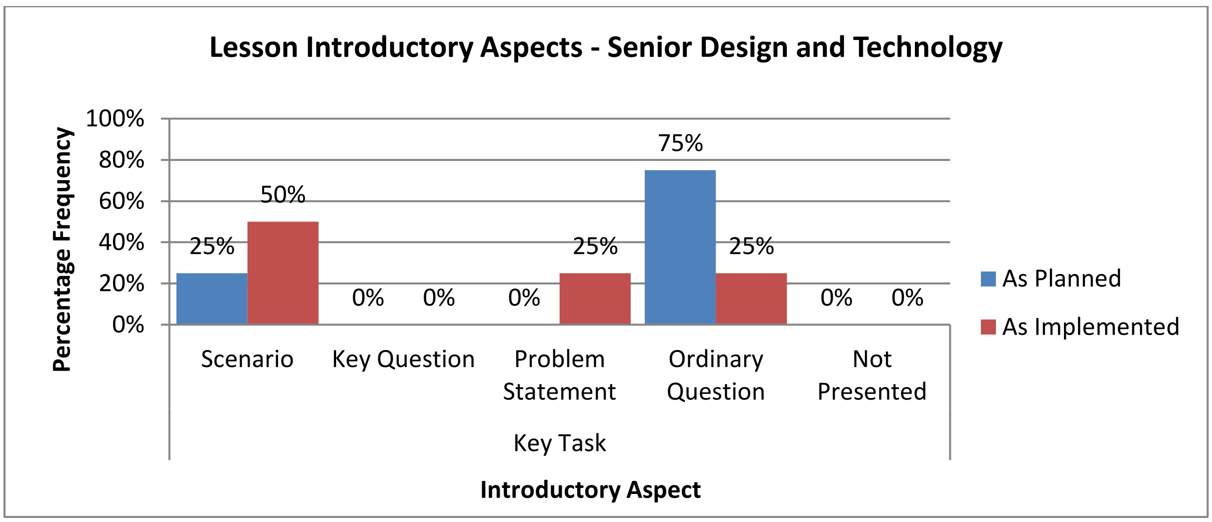


Figure 131: Lesson Introductory Aspects - Senior Design and Technology

At junior level the findings revealed that the total average score in scenario was 50% at planning stage as compared to 33% at implementation stage representing 17 percentage point decrease. Additionally, there was 17 percentage points increase in problem statements at implementation stage. Similarly, at planning stage, the ordinary questions were 50 % and 33 % at implementation stage representing a 17-percentage point decrease. Further, key questions were not presented at both planning and implementation stages.

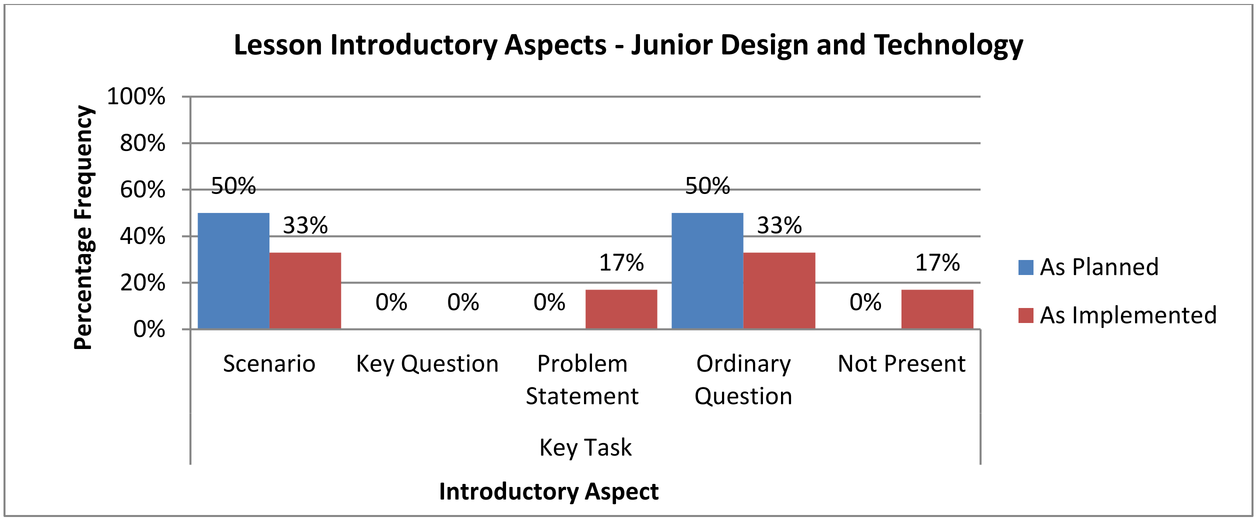


Figure 132: Lesson Introductory Aspects - Junior Design and Technology

The results indicated that the teachers of Design and Technology had relatively low abilities in the area of lesson introduction and might require intensive training to sharpen the skills in lesson preparation and delivery. This is so because Design and Technology is such an important area of study that has the potential to improve the livelihood of many as the practical skills in the subject contained therein have wider applications in society. From the lessons observed some key introductory aspects were not planned and subsequently not executed. Not completely using key tasks might imply that teachers had limited knowledge and understanding on how to execute the introductory lesson activities as envisioned in STEM Education. This could suggest that there were inadequate pedagogical skills needed to put into effect the planned lesson introductory activities. Additionally, the low utilization of key tasks such as scenarios and key questions at both senior and junior levels implies that, teachers were still being influenced by positivists' approaches. Further, the variations in the planned and implemented introductory aspects raises concern as it might entail that adequate time was not assigned to the planning process hence, the change at delivery from what was planned initially. Another reason might be that, teachers have inadequate subject content matter and pedagogical skills to enable them effectively plan and implement appropriate introductory activities. Figure 133 shows a case in which the implemented introductory aspect was not the one planned for.

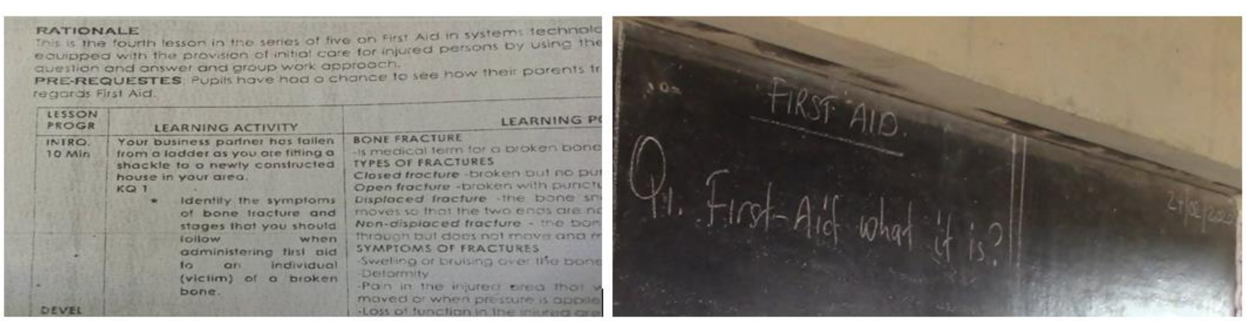


Figure 133: Sample Introductory Key Aspects - Design and Technology

It is also evident from Figure 133 that teachers have challenges in questioning techniques. To enhance critical, creative and analytical thinking in the learners there is need to effectively use thought provoking questions.

f) Hospitality & Tourism

Figures 134 and 135 indicate results for lesson plan introductory aspects in Hospitality and Tourism at both senior and junior levels respectively.

The findings at senior level show that no attempt was made at both planning and implementation stages regarding the use of any of the recommended key tasks as introductory activities. Instead, only ordinary questions were planned and used during delivery as introductory activities.

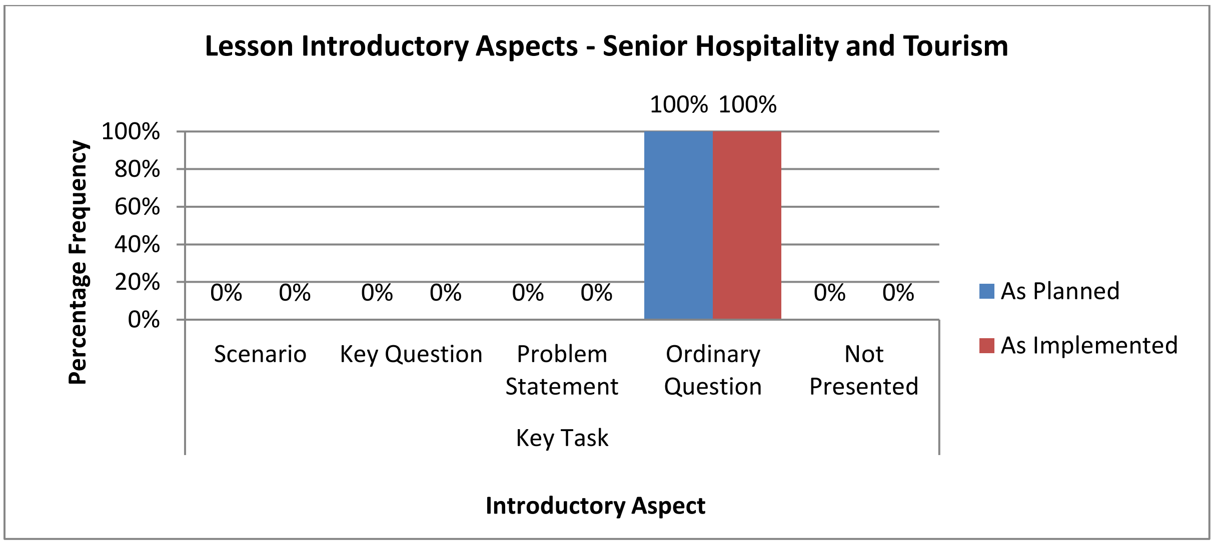


Figure 134: Lesson Introductory Aspects - Senior Hospitality and Tourism

At junior level, just like the situation was at senior level, only ordinary questions were planned and executed as introductory activities with no reference whatsoever to any of the proposed key tasks to be used in STEM Education.

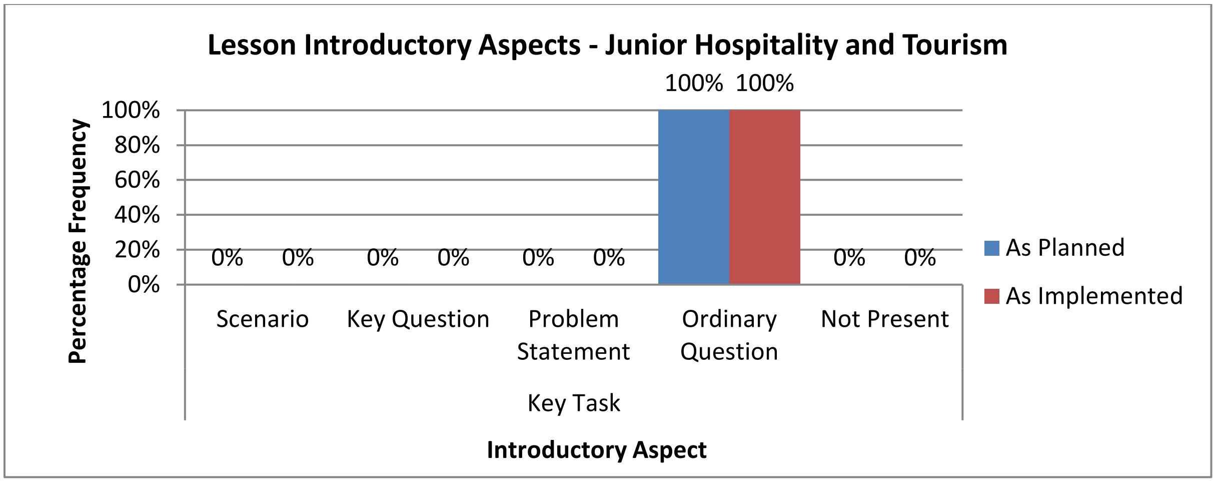


Figure 135: Lesson Introductory Aspects - Junior Hospitality and Tourism

The beginning of a lesson ushers learners into the expected activities during teaching and learning as it gives them an idea about what should be coming for that particular interaction with the teacher. Therefore, it should be motivating, relevant and memorable in order to help learners develop interest in the content to be learnt and retain the most important points of the lesson. However, results of the findings for Hospitality and Tourism regarding lesson introductory aspects should be a source of concern in STEM Education as the prevalence of ordinary questions may not inspire learners to become creative. The predominance of the ordinary questions as introductory activities both at planning and implementation stages may be caused by incompetencies in teachers on what key tasks are and how to construct and utilize them. Figure 136 shows the type of questions which were referred to as key tasks.

Figure 136: Sample questions as key tasks in Hospitality and Tourism

It is apparent from Figure 137 that the questions planned and presented were non-thought provoking as they required straight forward responses. Such basic questions cannot help to develop the expected learner in STEM Education. To this effect, concerted efforts would be needed to bring teachers to the level of full understanding on how to phrase key tanks and their essence in a lesson.

g) Mathematics

The Mathematics senior and junior level results regarding lesson introductory aspects are shown in Figures 137 and138 respectively.

At senior level, the findings disclosed that there was adherence to planned ordinary questions as 80% of the lesson plans indicated having planned to use them as introductory tasks and these were executed accordingly during the introduction of lessons. Contrariwise, the findings also revealed inadequate use of key introductory tasks as neither of the lessons utilized neither key questions nor problem statements with only 20% of the lessons having used scenarios. Additionally, there were also disparities in the planned lesson introductory key tasks with the presented ones. This was evident as the scenarios presented in the lessons were not planned for and the key questions planned at the outset were not put forward during lesson implementation as seen in Figure 137.

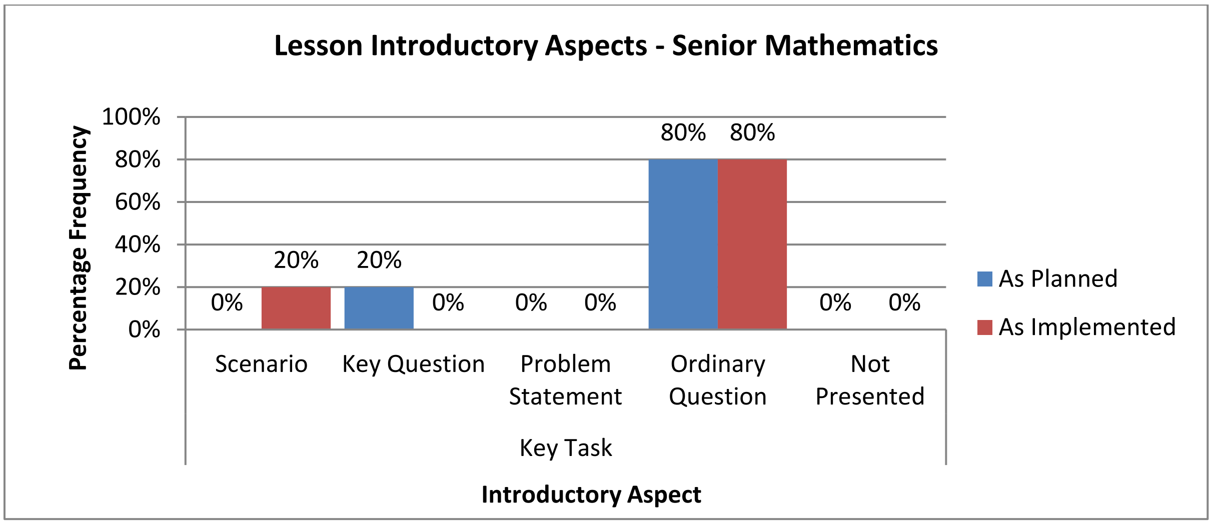


Figure 137: ***Lesson Introductory Aspects - Senior Mathematics***

At junior level, there was inadequate use of key tasks as none of the lessons had problem statements and key questions presented during lesson introductions with only 33% of the lessons having used scenarios as introductory activities. Just like at senior level there were also differences in terms of what was planned and implemented. None of the scenarios presented were planned for and the problem statements planned for were not implemented. As regards to ordinary questions, despite the above average use, there was 16% decrease as only 67% were presented out of the 83% that were planned.

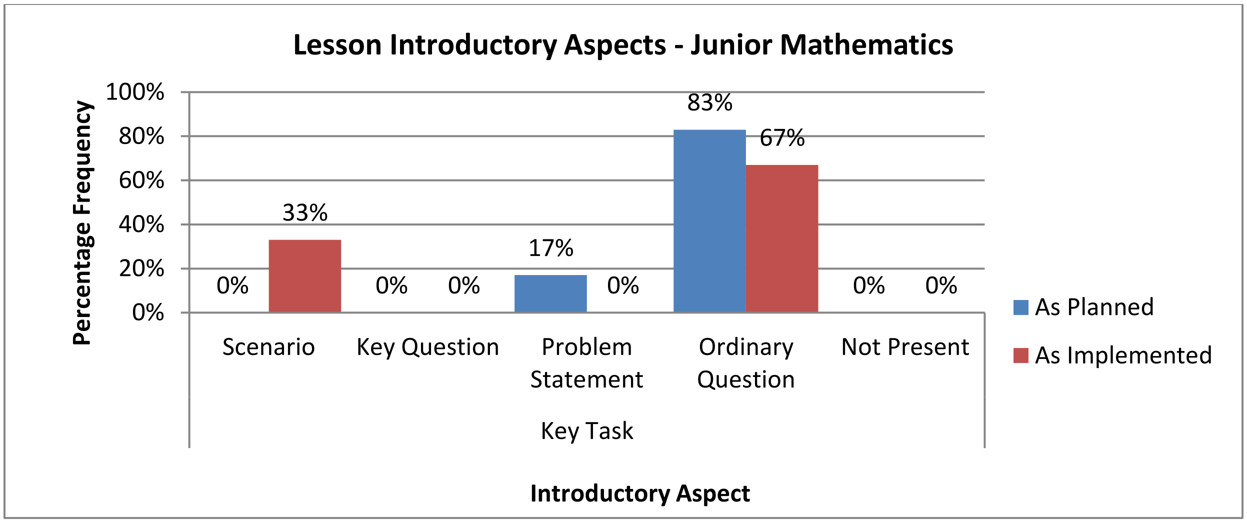


Figure 138: Lesson Introductory Aspects - Junior Mathematics

The considerable use of ordinary questions as opposed to recommended key lesson introductory tasks at both senior and junior levels is evidence of the inertia to shift from the conventional positivist practices to the advocated constructivist approaches. This might be as a result of reluctance by teachers to employ constructivist methods. Another reason might be the inadequacy of teachers' pedagogical competencies. The use of more ordinary questions implies that the start of the lessons may not follow an inquiry-based constructivist model and thereby making it difficult to transit into the lesson activities. This is so because the use of ordinary questions cannot set the correct pace into building the desirable STEM mathematical understanding in the learners.

Regarding the discrepancies in terms of what was planned and implemented entails that teachers might have inadequate knowledge and pedagogical skills on formulation and presentation of recommended introductory key tasks in STEM teaching and learning. Additionally, despite some lesson introductions having planned and implemented key tasks, there still seemed to be challenges in the formulation and presentation. Below are lesson introductory cases presented as key tasks.

> *Case 1*: "*A man has a balance of K150.00 in his ZANACO account and his brother credits his account with a K250.00. If the bank allows him to withdraw a K573. 00. If the withdrawal charge was K10.00. What will be his account balance*"?

> Case 2*: "From sea*-*level, a submarine descends 40 meters per minute. Where is the submarine from sea-level 5 minutes after it started descending"?*

From the cases above, in as much as the key tasks posed might stimulate analytical thinking, they did not give provision for learners to think hypothetically. Learners did not engage in uncovering the depth of a concept as they worked through the key tasks instead, they aimed at giving pat answers. Key tasks are supposed to be framed in such a way that they stimulate learners thinking and sustain learning. The inclination to product as opposed to being process driven as seen in Cases 1 and 2 is an indication of the existing challenges in designing and executing appropriate key tasks. There is need therefore to engage teachers of Mathematics in customized Professional Development Activities in order to enhance their PCK.

h) Physics

Figures 139 and 140 shows results in senior and junior lesson introductory aspects observed in Physics respectively.

Considering the senior lessons, there were discrepancies in terms of planned and implemented key lesson tasks. The scenarios presented were not planned for and equally, the key questions planned for were not presented.

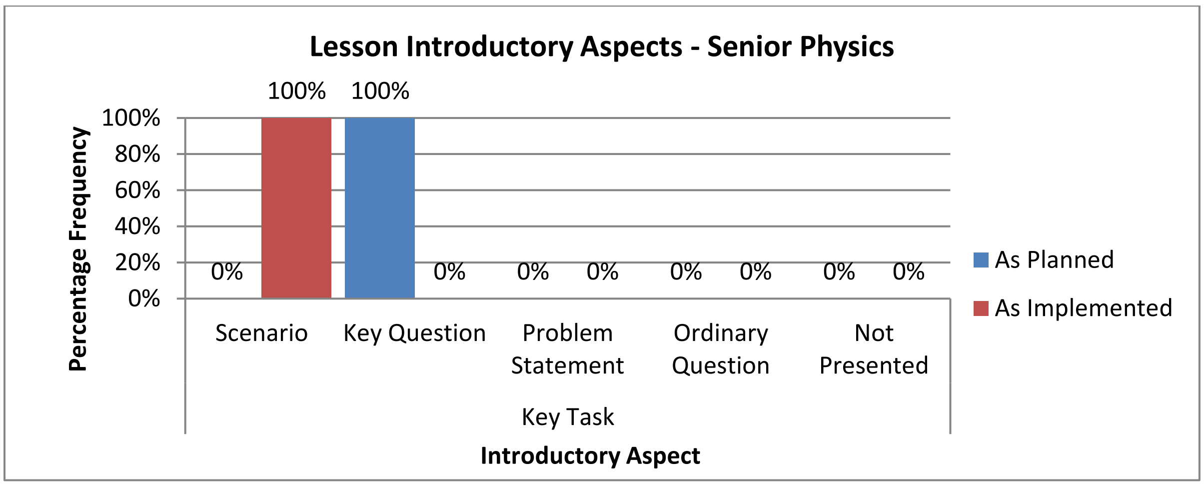


Figure 139: Lesson Introductory Aspects - Senior Physics

At junior, just like at senior level, there were differences in terms of lesson introductory aspects planned for during the lesson planning stage with those implemented during the lesson delivery stage. Fifty percent of the planned key questions were not presented during delivery and 50% of the ordinary questions presented were not planned for as can be deciphered from the 25% and 75% planned and implemented respectively. There was also average and non-execution of key lesson introductory tasks as indicated in Figure 139 where none of the lessons had key questions and problem statements as introductory aspects whilst only 25% of the lessons used scenarios.

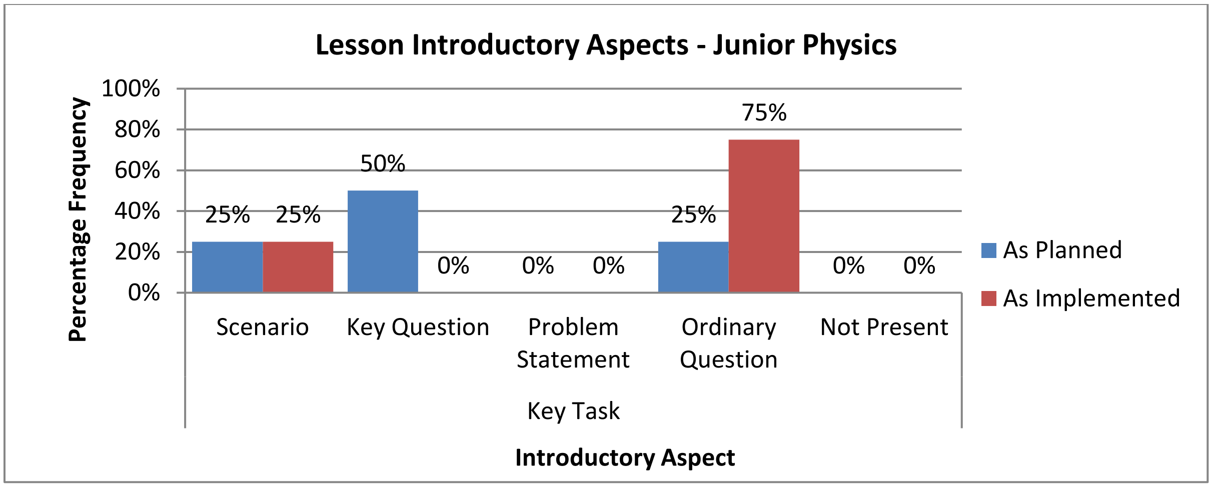


Figure 140: Lesson Introductory Aspects - Junior Physics

The differences between what was planned and implemented raises concern as it may entail unpreparedness of teachers due to ineffective planning. It may also be due to inadequate PCK and skills on the part of teachers to present what was planned. In order to get the learners interested in learning, teachers do not need to impetuously present introductory activities. The introductory key tasks need to be developed by taking into consideration learners' conditions. To do so a great deal of time and effort should to be committed to planning.

Additionally, the use of more ordinary questions during lesson delivery at junior level, despite having lowly planned for them initially is evidence enough of positivism being the teachers comfort zone. This shows that teachers are still struggling in terms of adaptation of the constructivist teaching and learning approaches. To strengthen the teachers of physics PCK professional development assemblies may include customized activities that encompass lesson introductory aspects.

4.1.8. Summary of Introductory Lesson Aspects

Figures 141 and 142 show summary lesson introductory aspects across all the STEM subjects observed at senior and junior levels respectively.

At senior level, there were below average plans and use of the recommended key tasks. Additionally, there were variations in what was planned and implemented. The total average score in scenarios was 15% at planning stage as compared to 34% at implementation stage representing 19 percentage points increase. As regards with key questions the planned 18 % average score was not implemented. Further, the total average score in problem statements at planning was 9% and 14% at implementation stage representing a 5-percentage point increase. With ordinary questions, the total average score at planning was 58% and 46% at implementation stage representing a 12-percentage point decrease.

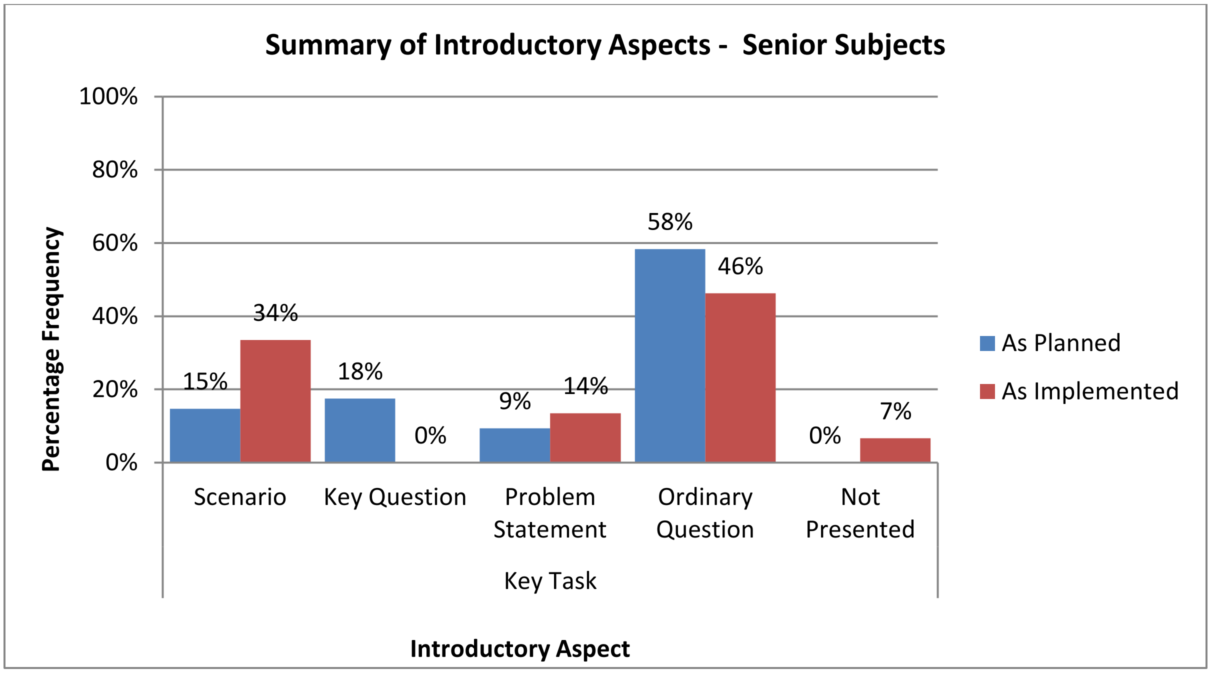


Figure 141: Summary Introductory Aspects – Senior Subjects

At junior, as was the case at senior level, there were equally below average plans and use of introductory key tasks. There were also disparities between the planned and implemented lesson introductory aspects such as scenarios, key questions as well as ordinary questions. Sixteen percent of scenarios were planned for while 30% of them were presented in the lessons. In terms of key questions 13% were planned for but none were implemented in all the lessons. Despite the 6-percentage variation between the planned and implemented ordinary questions, they were the most prevalently planned for and used as indicated in Figure 142.

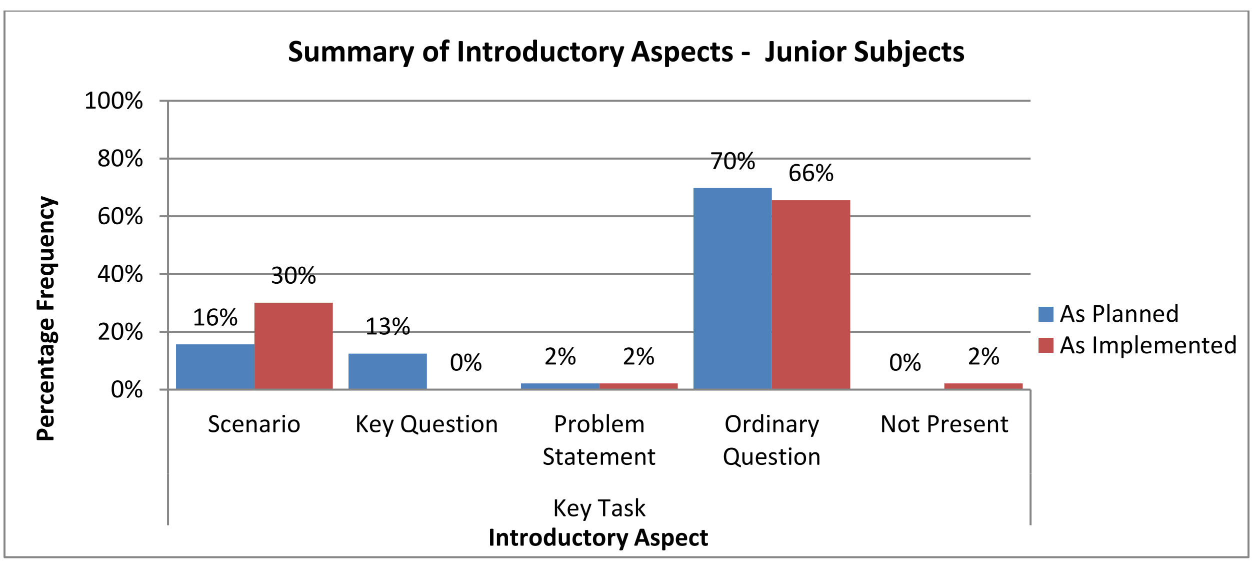


Figure 142: Summary Introductory Aspects – Junior Subjects

The differences exhibited at planning and implementation might be that teachers were inadequately prepared for the lessons. This is so because they may have considered planning as a formality to adhere to the standards that one needed to have a lesson plan before teaching and so planning was not given the seriousness that it deserved. Planning for lessons is important as it gives a clear indication on how the learning process will take place. The variations between the planned and implemented lesson introduction activities may also mean that there were inadvertent introductory aspects presented in the lessons. Such impromptu presented introductory aspects may not have the ability to engage the learners and bring out their inquisitiveness as expected. This may ultimately impede the acquisition of desired learning outcomes. Further, the use of more ordinary questions is evidence of the substantial positivist influence on the teachers' pedagogical skills and hence the struggles to adapt to constructivist approaches.

4.1.9. Lesson Development

Lesson development is a very vital part of lesson delivery. It involves unfolding of lessons in which learners play a critical role as they, design, present solutions and demonstrate understanding of divergent ideas. In this research, lesson development focused on whether there were individual learning strategies or group learning interactions employed. Additional focus was also on whether the lesson activities took a constructivist flow as well as how the lesson consolidation was done.

Unlike positivism, constructivism entails teaching and learning that is focused on the learner as in a more interactive learning environment. The lesson delivery process will depict constructivism if the learners are placed at the centre of the teaching and learning process. The learners should be able to construct their own knowledge. To do so, teachers as facilitators should provide quality experiences to learners for meaningful learning to take place. Teachers need to provide various learning opportunities that need to engage learners in individual conceptualisation, discussions with peers, generation questions, designing research, solving problems as well as providing solutions. While the potential benefits of group interactions cannot be understated, in STEM teaching and learning individual tasks are equally important as they help in the preparation of personal ideas on a concept. It is helpful for learners to undertake this kind of personal encounter with a concept before they engage in learning teams. Further, teachers should provide opportunities for lessons to be consolidated. In consolidation, learning ideas are clarified and enforced so that learners are not left uncertain. There are various ways in which lesson consolidation could be done. However, making learners to consolidate lesson concepts is beneficial as it helps them internalize knowledge and skills.

The results and analysis of lesson development aspects across subjects and grades were:

a) Agricultural Science

Figure 143 shows results of lesson development aspects in Agricultural Science lessons observed at senior and junior levels. The findings revealed that at senior level no lessons had used a combination of group and individual teaching and learning strategies. Sixty seven percent of the lessons used group work while 33% used individual work. At junior level, group work was predominantly used as none of the lessons incorporated group and individual strategies nor used individual strategies only. At both senior and junior levels, the flow of activities was largely constructivist as indicated by the 67% and 100% respectively. However, 33% of senior lessons and 100% at junior level were not consolidated.

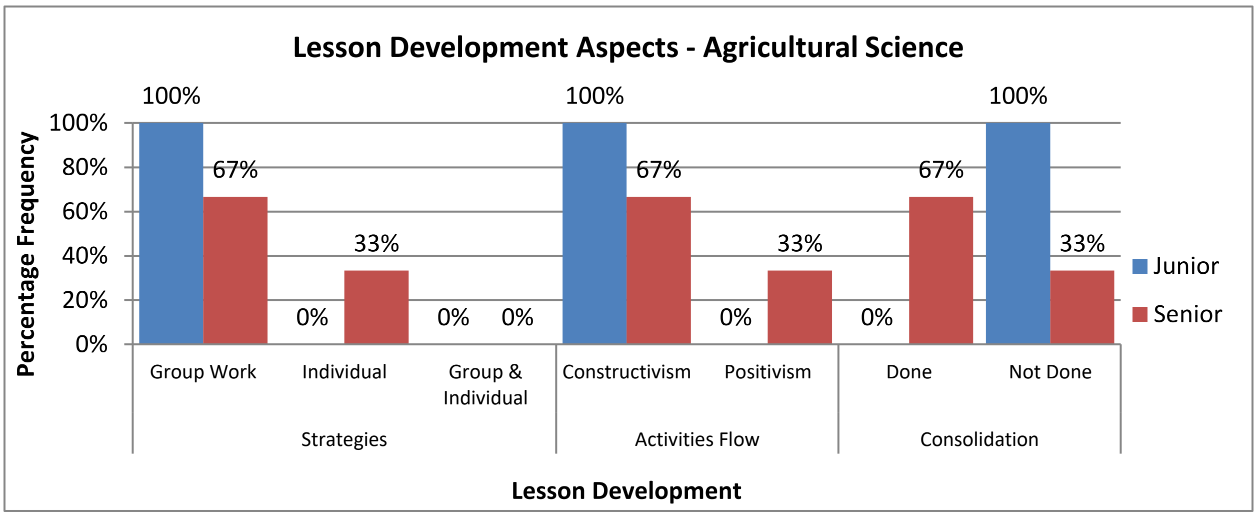


Figure 143: Lesson Development in Senior and Junior Agriculture Science

The observations from the findings were that teachers preferred the group work as well as individual work and that constructivism approaches were being applied to some appreciable extents. The considerable constructivist flow of activities may suggest that teachers had understood that learners needed to be placed at the centre of learning in STEM Education. In addition, it might also mean that teachers were gaining ground as regards to the use constructivist approaches. This was evident as more at both levels mainly used group work learning strategies. Group work strategies enable learners to develop acquisitive and communicative skills through sharing ideas. In as much as group work provides a favourable learning environment it needs to be carefully planned for in order for it to help support learning. Additionally, use of mixed strategies, in the same lesson, is encouraged in order to cater for all learners who may have different learning abilities. It is recommended that teachers of Agricultural Science continue enhancing their pedagogies by strengthening CPD activities at all levels.

b) *Biology*

The results in Figure 144 shows lesson development aspects in Biology lessons observed at senior and junior levels. The findings indicated that at both senior and junior levels group work strategies were predominantly used and that no lessons had used a combination of group and individual teaching and learning strategies. In addition, individual strategies by themselves were not used at both levels. The flow of activities was more positivist inclined at both senior (67%) and junior (50%) levels. However, 67% and 50% of senior and junior lessons respectively were consolidated.

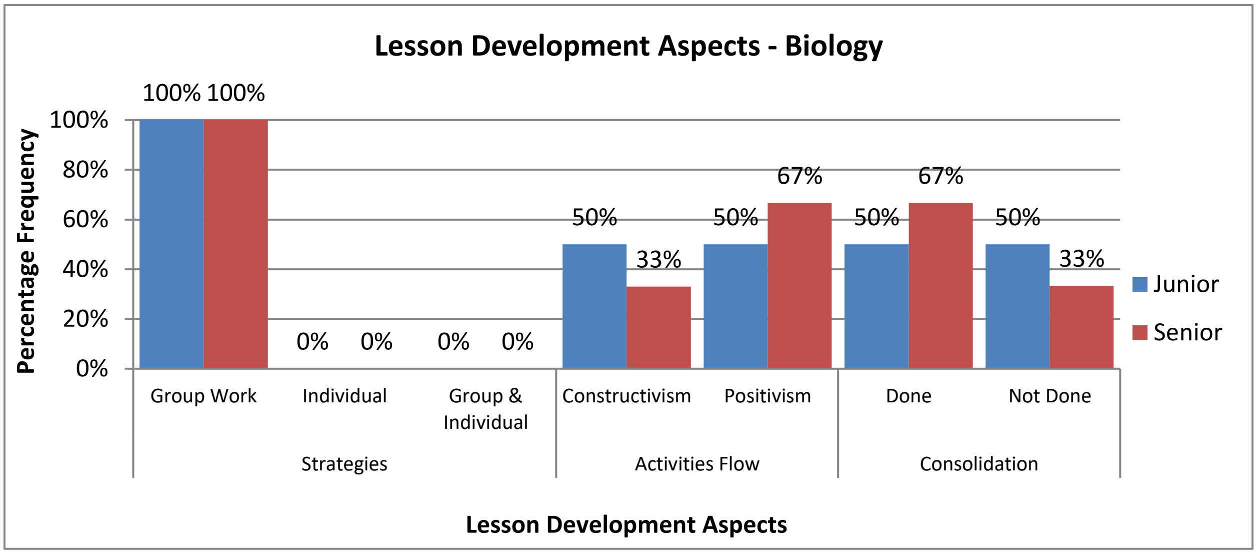


Figure 144: Lesson Development for Senior and Junior Biology

The findings indicated that, teachers preferred group work strategies only and that constructivism and positivism approaches were at average and slightly above average respectively. The considerable positivist flow of activities may suggest that teachers are still not acquainted with the constructivist approaches recommended in STEM Education. The implications of the results would be that learners might not be able to acquire the skills needed for the 21st Century. Additionally, it may also mean that learners could always want to be doing activities in groups even when the potential to do them individually could be found within. This might start promoting laziness in as far as task executions at individual level would be concerned. Rigorous training would be required to lure the teachers into practicing constructivism as they seem to have entrenched in positivism approaches which they have been enthusiastically applying for many years.

c) *Chemistry*

In the Chemistry lessons which were observed, it was found out that the most prevalent strategy used by the teachers of Chemistry was group work standing at 100% junior and 75% senior while the combination of group and individual teaching and learning strategies was not utilized at both levels. Additionally, it was observed that the junior lessons took the approach of positivism (100%)

while 75% of the senior lessons implemented constructivism as shown in Figure 145. Furthermore, 50% of senior lessons were consolidated while the junior lessons were not consolidated.

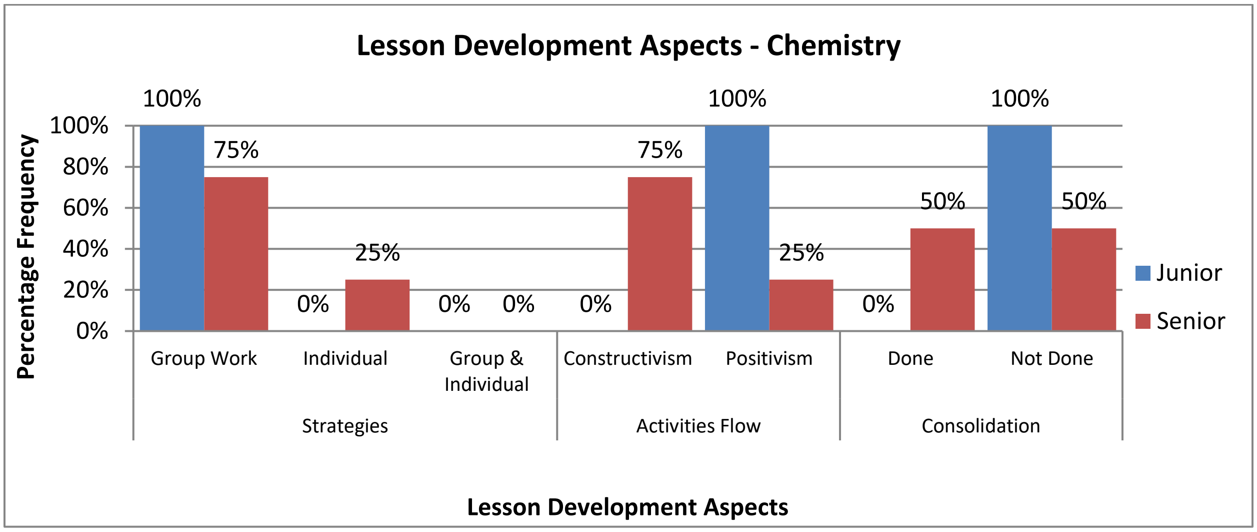


Figure 145: Lesson Development for Senior and Junior Chemistry

In as much as the teachers at senior level implemented constructivism to a higher extent the results still showed that there was considerable inclination in some teachers towards positivism as the preferred approach. This is a source of concern which requires concerted efforts to impel the teachers of Chemistry so as to help them become accustomed to constructivists' approaches. One way of achieving this would be strengthening capacity building programmes, at all levels, on how to apply constructivism with concrete references to specific content.

d) Computer science

Figure 146 shows results for lesson development in Computer Science at both junior and senior levels. The findings reveal that the commonest strategy used was group work which was 60% at senior level and 100% at junior level. The nature of activities at junior level was average, exhibited by 50% positivism and 50% constructivism compared with 40% positivism and 60% constructivism at senior level. The junior lessons were not consolidated at all while 60% of the senior lessons were consolidated.

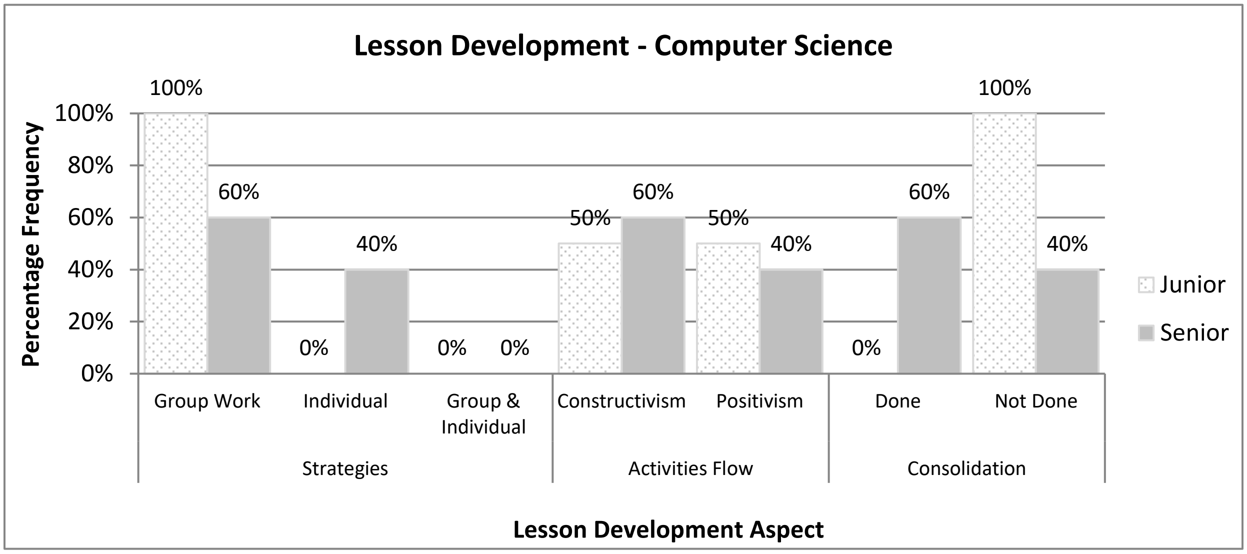


Figure 146: Lesson Development for Senior and Junior Computer Science

The results indicate that group work was more widespread than individualized work while none of the lessons used the combined strategies during lesson delivery. This may suggest that teachers would want learners to discuss and share ideas in the groups. The above average (60%) and average (50%) use of constructivism approaches, at senior and junior levels respectively, were positive indications regarding the flow of activities. This may be due to the training that most teachers attended at National Science Centre prior to the commencement of the STEM Transitional Curriculum implementation. However, the marginal difference between constructivism and positivism approaches may not be a good indicator of the degree of shift from the old ways of teaching. To this effect, efforts should be made to bring on board all STEM teachers by encouraging them to engage in CPD activities through Lesson Study.

e) Design and Technology

Figure 147 shows lesson development aspect results for Design and Technology at both senior and junior levels. The findings disclose that there was above average exclusive use of group learning strategies at senior (50%) and junior (66%) levels. The results additionally revealed below average use of exclusive individual and combined learning strategies. Further, it was observed that the flow of lessons activities was highly positivist as indicated by the 67% and 83% at senior and junior levels respectively. In terms of consolidation, 33% of the senior lessons and none of the junior lessons had reinforced lesson ideas. This meant that only 67% of the senior lessons were consolidated.

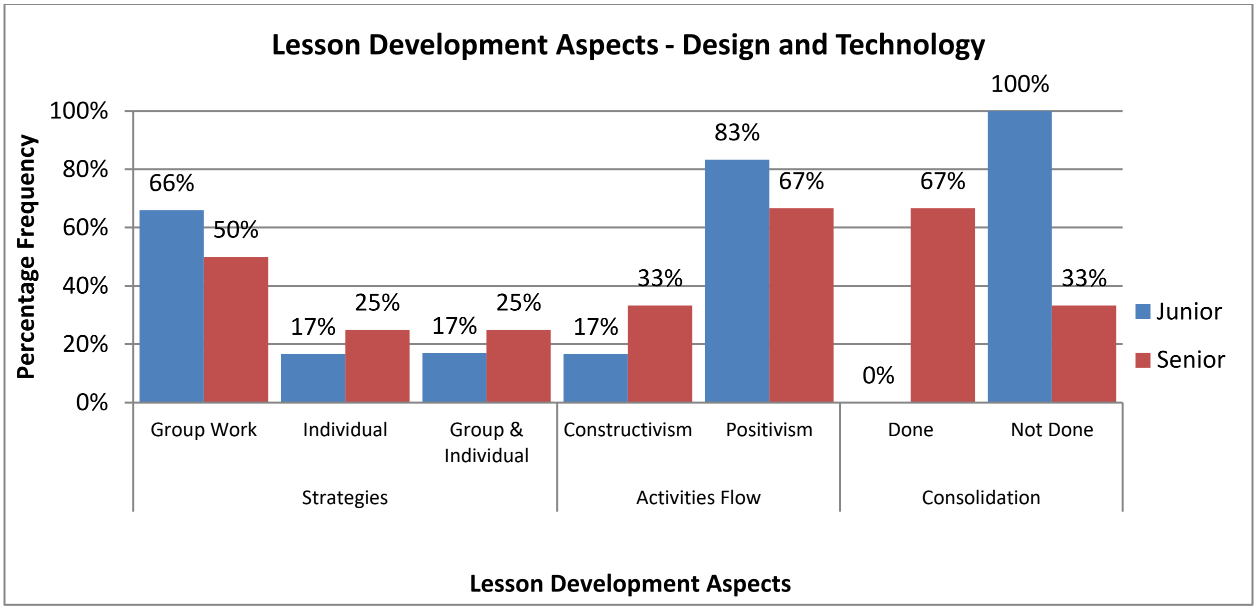


Figure 147: Lesson Development for Senior and Junior Design & Technology

The use of a combination of both group and individual learning strategies regardless of being low is an indication of teachers attempting to take into consideration the fact that learners construct and acquire knowledge and skills differently. In as much as group strategies provide a wide range of learning benefits, it is also important that learners are given time to have individual cognitive perception before they cluster into groups. This is in order to ensure that learners have their own personal conceptual understanding which can be shared in the groups. This might enrich the groups' interactions and help provide a wide range of information to be shared. Therefore, instructional strategies in STEM Education should be designed to deliver and address diverse learner needs. To do so teachers should create opportunities for learners to demonstrate learning in different ways hence mixing individual and group strategies may be helpful. Further, the positivist inclination of lesson activities raises concern as it is evidence of the challenges teachers had to transit from the teaching and learning approaches, they were so much grounded in. STEM teaching and learning is aimed at enabling learners become all round thinkers by providing knowledge, skills and values that strengthen the learners' problem-solving abilities. To achieve this, learners should be engaged in the learning process and teachers should take the role of facilitators by providing suitable learning opportunities. The implication of lesson activities being biased towards positivism is that there might have been more focus on the learners gaining correct knowledge unlike constructing their own knowledge. This may ultimately hinder the achievement of desired STEM learning outcomes. To remedy this customized professional development activities, need to include aspects of lesson delivery.

f) Hospitality & Tourism

The results shown in Figure 148 indicate the findings of lesson development aspects in Hospitality and Tourism at both junior and senior levels. The findings showed that, at both junior and senior levels, only group work was used as a strategy during lesson delivery. Additionally, all the lessons were tailored towards the positivist approach as no aspects of constructivism were exhibited. However, lesson consolidation was considered at both levels.

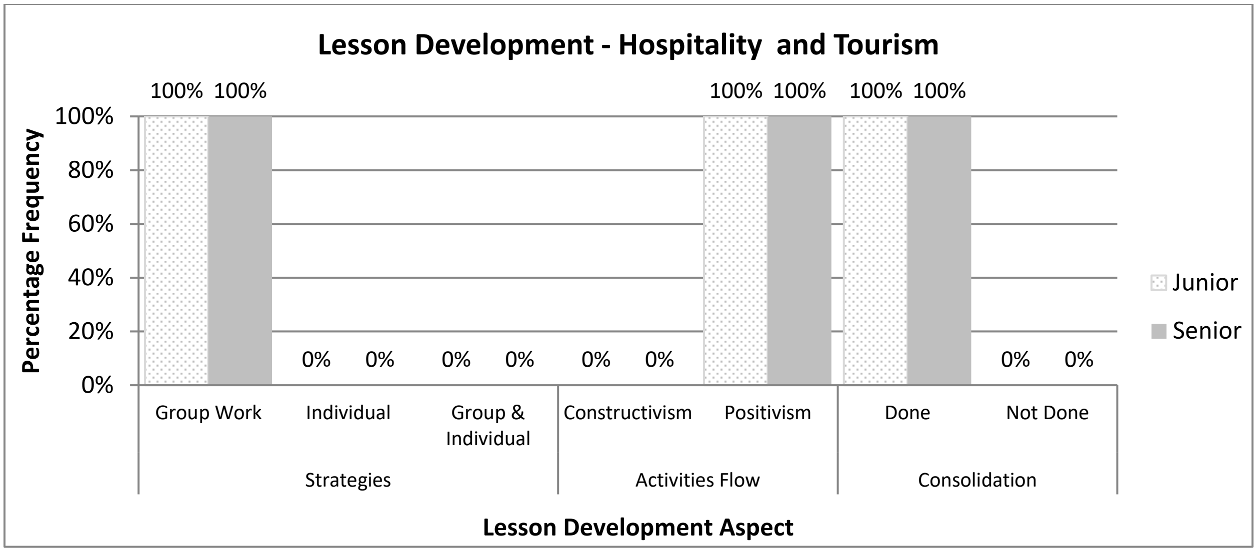


Figure 148: Development for Hospitality and Tourism at Both Senior & Junior Levels

From the findings it was observed that the strategy of preference at both junior and senior levels was group work. This may be due to teachers' thinking that putting learners in groups meant constructivism even when the teachers' approaches were positivist in nature. The implication of these results could be that teachers might take long to realise what constitutes constructivism thereby stalling the development of learners as anticipated by STEM Education. Additionally, although consolidation was indicated to have been done there was no evidence pointing to how the misconceptions would be handled. As a result, some misconceptions actually arose from the point of view of teachers as the case was for one lesson where it was said that "*failure by elderly people to crackle their knuckles is caused by lack of water in the body"*. Arising from these observations, it becomes abundantly clear that teachers need to engage in intensive professional development activities in order for them to interpret and implement the intentions of the Curriculum effectively.

g) Mathematics

The results in Figure 149 show Mathematics lesson development aspects at both senior and junior levels. The findings revealed that at both levels, exclusive group learning strategies were more prevalent than individual ones as well as mixed (individual and group) strategies. Additionally, there was below average constructivist flow of lesson activities at both senior (40%) and junior (33%) levels. This meant that lesson development activities were more positivists' in nature. Further, there was above average (60%) and outstanding (100%) lesson consolidation in the senior and junior lessons respectively.

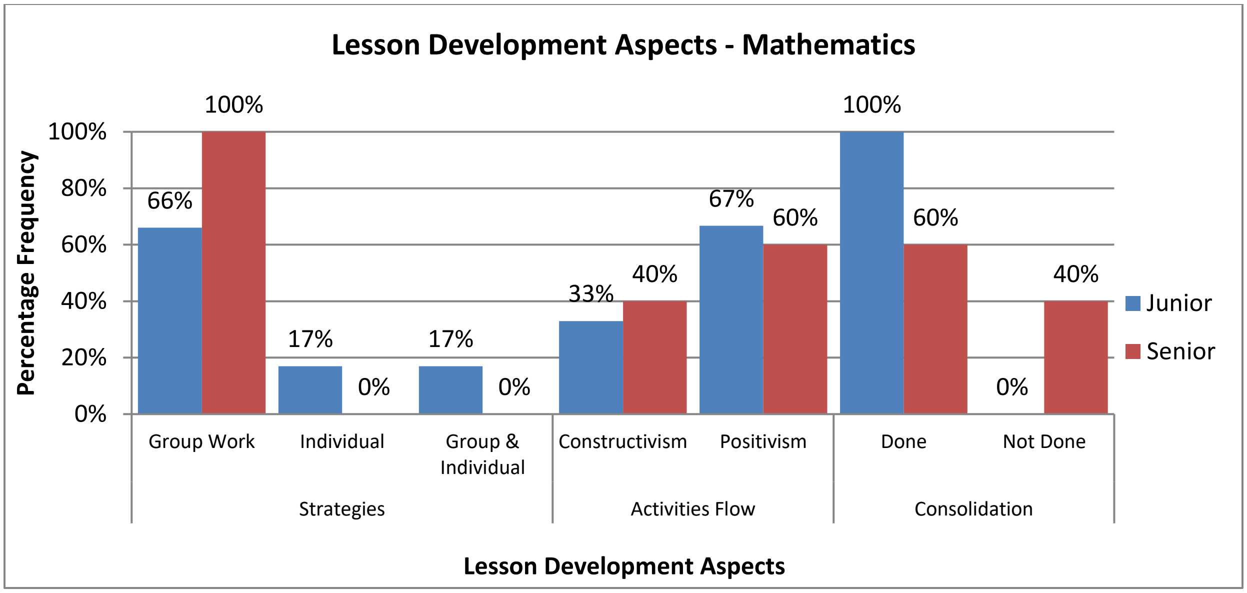


Figure 149: Lesson Development for Mathematics at Both Senior and Junior Levels

The considerable use of exclusive group teaching and learning strategies at both senior and junior levels implied that learners had opportunities to discuss, critique and refine each other's ideas. Group work encourages collaborative and argument-driven classrooms that are more successful than traditional classrooms for improving academic achievement (Capar & Tarim, 2015). The placing of learners in groups meant that learners were able to interact and through this interaction their critical thinking and problem-solving skills were expected to be enhanced. Through the group presentations learners expressed themselves and compared different ideas and this was to ultimately enhance their Mathematics understanding. In as much as group work provides opportunities for learners to engage in discussion, exchange and communicate ideas, they should also have initial individual prospects in cognitive thinking, designing and justification before they get into groups. This could foster effective individual input when learners get into groups (Bryan, Moore, Johnson, & Roehrig, 2016). Therefore, in order to ensure effective learning, not only the combined use of both strategies is encouraged but also careful designing of lesson activities to benefit the differently abled learners.

Additionally, there is concern caused by the revelation that the flow of activities in most lessons was not constructivist in nature. The positivist disposition was clear evidence that learners were being engaged in procedural rote learning in the quest to find answers. This is an indication that there was fixation of teachers in their 'chalk and talk' comfort zone as they still had the tendency of falling back on teacher centred ways of lesson delivery. The following is an illustration depicting positivist aligned cases:

> Case 1: "*A boy had two colours of shirts blue and yellow. List the two choices he could make and state the number of these choices*" then later the task for learners

was "*a girl had no fruits in her pocket. List and find the number of choices she could make"*

Case 2: "*Round off length and width of the board to the nearest one and two decimal places*" thereafter a group activity was to "*round off 4.6666 and 2.0007 to two decimal places…*" followed by individual task to "*round off 48.57 to the nearest second*"

From the above cases, it was evident that the lesson activities were centred on procedural literacy as they merely focused on development of computational skills. To effectively learn Mathematics in STEM both procedural and conceptual knowledge should be incorporated in the instruction, otherwise the learning would simply entail dealing with numbers and not bringing out the desired skills to help learners apply the concepts in their everyday life.

Furthermore, within the development stage, lesson ideas presented by learners needed to be confirmed in order to clarify learning points and come up with common view points. However, the non-consolidation of some lessons at junior level might have been as a result of teachers having inadequate pedagogical content knowledge to enforce and clarify lesson aspects. The implication of non-consolidation of lessons is that learners' misunderstandings, errors and misconceptions would not be cleared. In order to effectively deliver lessons that have proper use of constructivist activities, teachers of Mathematics need to devote time to professional development undertakings. These undertakings should include pedagogical and content lesson delivery aspects.

h) Physics

Figure 150 shows results of lesson development aspects in Physics lessons observed at senior and junior levels. The findings disclosed that none of the lessons at both levels incorporated group and individual learning strategies in the same lessons nor used individual strategies exclusively. Group learning strategies were more prevalent as represented by the 100% at both senior and junior levels. It was also observed that all the lessons' activities at senior level flowed in a constructivist nature whilst only 25% of the lessons at junior level had lesson development activities exhibited in the aforementioned approach. This meant that 75% of the lesson development activities at junior level were positivist in nature. As regards to reinforcement of learning, 75% of the junior and 100% of the senior lessons were consolidated.

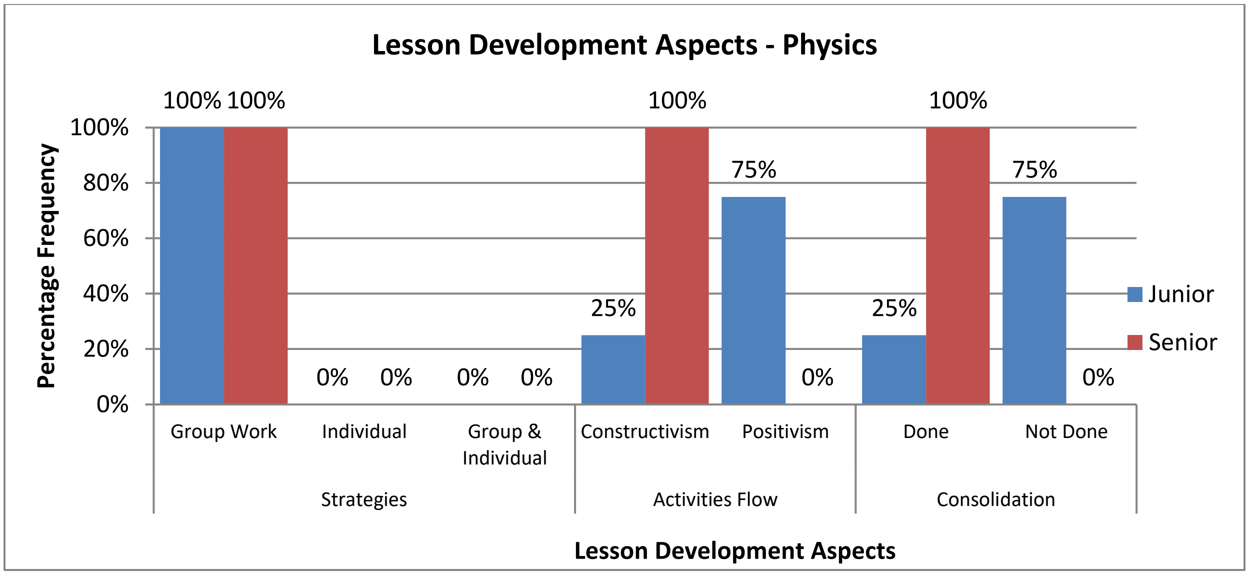


Figure 150: Lesson Development for Physics at Both Senior and Junior Levels

The observed below average constructivist flow of lesson activities at junior level is an indication that some teachers had heavy inclination towards positivist teaching and learning approaches. This is evidenced by the fact that teachers had continual challenges to acclimatize to suggested constructivist teaching and learning approaches in STEM Education. Additionally, having prevalent group work and a high disposition of positivism in lesson activities at junior level might mean that teachers did not carefully align the activities to suit the designated group learning strategies. For effective learning, all learners are supposed to participate in the groups as merely placing learners in groups does not entail constructivism. The size of the groups is also among the many factors to be considered during the planning for lesson development activities. The caption in Figure 151 shows group strategy endeavours observed in one of the Physics lessons.

Figure 151: Sample group dynamics

The group size was large that some learners were unable to interact with the teaching and learning materials. Therefore, the opportunities that group dynamics provide were not of benefit to them. At senior level, however, the outstanding constructivist lesson flow can be well associated with well-organized group learning strategies. The implication of this may be that learners will be able to share more information and gain better understanding of concepts. In addition, learners acquire teamwork skills which are among the essential valued society attributes. Although it may be good to have learners in groups, letting them operate individually at times might also be helpful to enhance independent thinking and creativity. Therefore, in STEM Education it is recommended that teaching and learning strategies should incorporate both group and individual learning strategies within particular lessons.

Further, the low consolidation of lessons at junior level raises concern as it suggests that there was no reinforcement of ideas in the lessons. The reason for this non-enforcement of lesson ideas might be that teachers had inadequate content knowledge and pedagogical skill on what, how and when to confirm the learner's ideas. It is important to consolidate lessons as it helps clarify conceptions, alternate conceptions and uncertainties. To this effect, professional development activities at all levels in Physics should include pedagogical aspects in order to enhance lesson delivery skills.

4.1.10. Summary of lesson development aspects

Figure 152 shows summary lesson development aspects in all the STEM subjects observed. The findings reveal that, on average, there was predominant use of group strategies at both senior (81%) and junior (92%) levels. Contrariwise, the use of individual and mixed strategies was lowly explored. As regards to the flow of lesson activities at junior level there was more of positivism as compared to constructivism whilst the opposite was true at senior level. In terms of lesson consolidation, more of the senior (71%) and few of the junior (34%) lessons were consolidated.

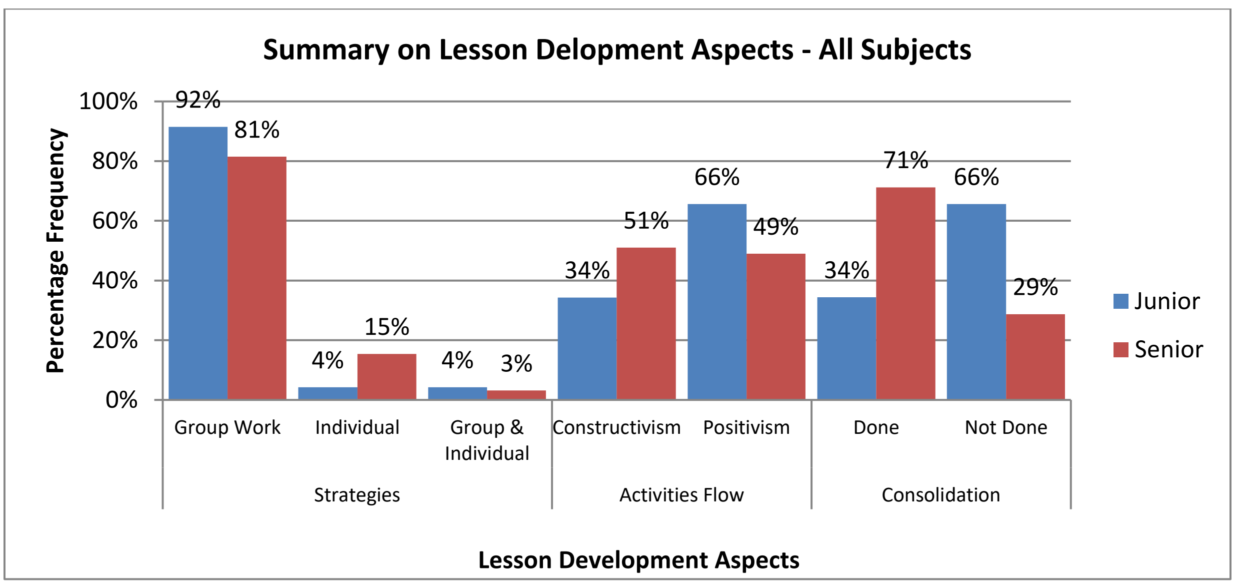


Figure 152: Summary of Lesson Development - All Subjects

The extensive use of cooperative learning, at both junior and senior levels, is an indication that teachers are according learners' opportunities to engage, interact, critique and share ideas during teaching and learning. In so far as group strategies bring widespread benefits dynamics of cooperative learning should be well considered in order to ensure that every learner contributes fairly and obtains better understanding of concepts. To ensure that effective contributions are made in the groups, it is important that learners should also have individual views before they get into groups. Therefore, combined use of both strategies is encouraged and also well-designed lesson activities which benefit differently abled learners should be crafted. Additionally, the fact that there were attempts of lesson activities flowing in constructivist manner is indication enough that teachers were slowly adapting to this way of teaching and learning. This is cardinal in STEM Education as constructivist approaches help learners to reflect on existing knowledge, construct new knowledge, evaluate the merits and demerits of newly constructed knowledge, and acquire skills based on their experiences.

Effective constructivist strategies should include reinforcement of lesson ideas. Therefore, having some lessons consolidated meant that lesson ideas and uncertainties that may have arisen in the learning process were clarified. Lesson consolidation is important as it reinforces learning points that learners have to process and make sense of in order for conceptual understanding to take place. In STEM learning consolidation can be done by both the teacher and the learners, however, the teacher plays a critical role of creating suitable opportunities for this confirmation of facts to be done. It is important for learners to be given a chance to confirm their peer's ideas as this helps them to ask questions and offer explanations. Issues of learner's misconceptions, difficulties and errors are best handled during the consolidation stage. Clarifying concepts and principles require discipline, careful observation and focus on details as the lesson progresses. This is so because in a lesson there will always be challenges arising from conceptions, misconceptions and errors from both teaching and learning points.

4.1.11. Lesson Conclusion

Lessons are like great narratives which require a meaningful ending that allows learners to reflect on how well they have achieved the lesson objectives. There are various aspects that could be considered during the conclusion of lessons. However, in this context lesson conclusions will involve how the lessons were summarized and evaluated. On one hand, lesson summary is the recapitulation of important lesson concepts that were learnt within the lesson. On the other hand, evaluation is the immediate assessment of the quality of teaching and learning process. Summary and evaluation can either be done by the learners, teacher or both. The results and analysis of how lessons were concluded across subjects and grades were:

a) Agricultural Science

The Agricultural Science results at both senior and junior levels, on lesson conclusion aspects, are shown in Figure153. From the findings, it was indicated that neither summary nor evaluation was done at junior level despite both being indicated in all the lessons at planning stage. At senior level both summary and evaluation were at 67% of the lessons had been summarised and evaluated.

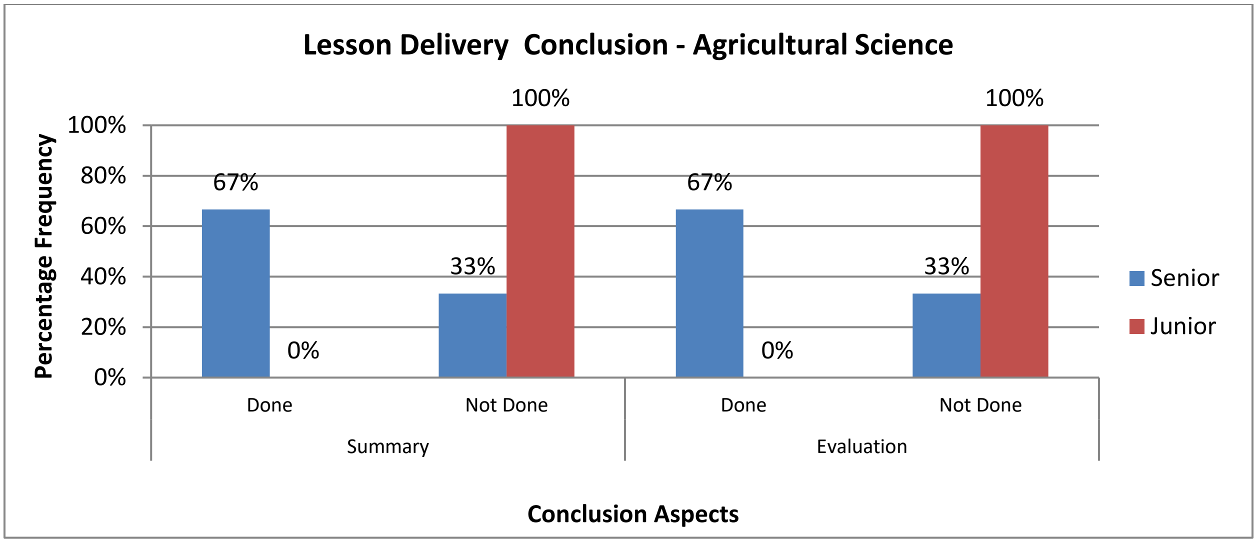


Figure 153: Lesson Delivery Conclusion for Agricultural Science at Both Senior and Junior Levels

The implications of the findings are that on one hand, learners at junior level completely missed out on the review of the day's lesson which should have helped them to piece the information together for better understanding. On the other hand, the teacher lost the opportunity to find out how much the learners had grasped and did not in order to reinforce on the aspects which might have eluded them for harmonization towards outcomes realization. These missed opportunities by learners may have been due to formalities that teachers perpetuate on paper with no intentions of executing what their plans indicate as seen in Figure 154 (lesson delivery conclusion) compared with Figure 75 (plan for lesson conclusion).

b) Biology

Figure 155 shows results of Biology lessons at senior and junior levels on lesson conclusion aspects. At senior level, the average percentage at planning stage (refer to Figure 76) for summary was 100% as compared to the 33% at implementation representing a 67% decrease. In case of evaluation, the total average percentage at planning was 33 % and no lesson was evaluated at implementation. At junior level, the total average percentage at planning was 100% and 50% was actualised at implementation. With regards to evaluation, all the lessons were planned to be evaluated but none of them were evaluated.

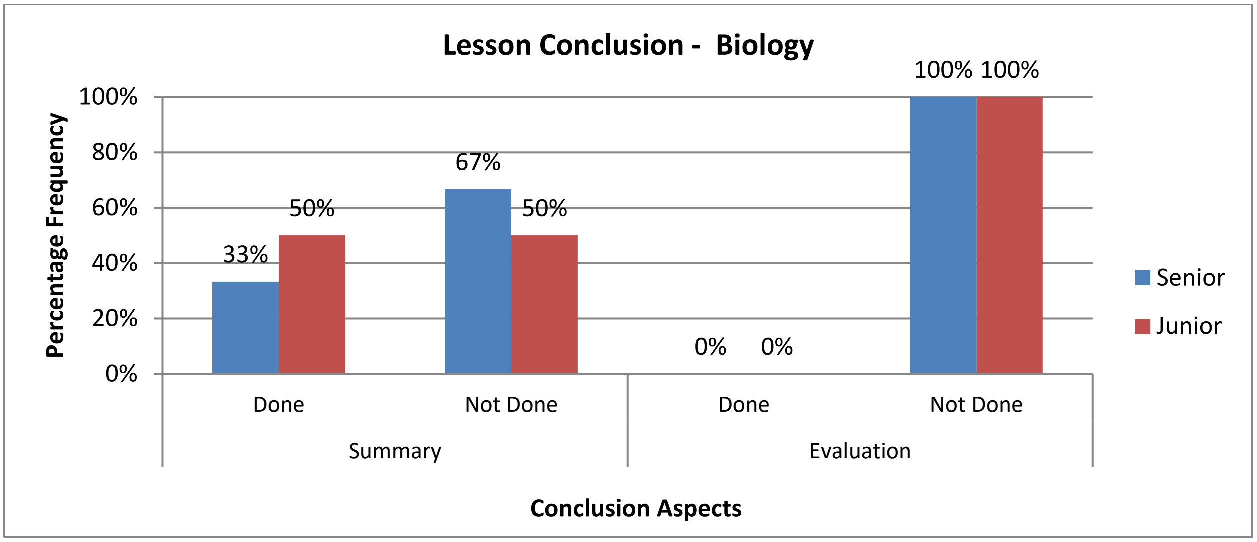


Figure 154: Lesson Conclusion for Biology at Both Senior and Junior Levels

There is consternation raised from the revelation of having no lessons not summarised at junior level as well as not being evaluated at both junior and senior levels. The reasons for this might be that teachers were not skilful enough to effectively conclude the lessons. The implications of these findings would be that learners' comprehension of the lessons' focus will not be coherent. In addition, it may be difficult to gauge whether or not the lesson outcomes were attained. From the decrease indicated between what was planned and implemented it is apparent that teachers of Biology had instructional difficulties as they failed to implement what they had planned. Further, not planning for evaluation and not evaluating the lessons might suggest the teachers' non-commitment to the teaching and learning process. In order to help teachers, and therefore learners, CPD through Lesson Study should be strengthened.

c) Chemistry

Chemistry results at both senior and junior levels, on lesson conclusion aspects, are shown in Figure156. From the findings, it was indicated that, at senior level, the total average % at planning stage for summary was 50 % (refer to Figure 77) and 75 % at implementation stage representing a 25 % increase, while 50 % of the lessons had evaluation planned for and 25 % were evaluated, representing a 25 % decrease. At junior level, all the lessons were planned to be summarised and all the lessons at this level were summarised at implementation stage. However, none of the lessons were planned to be evaluated and hence, all the lessons at this level were not evaluated.

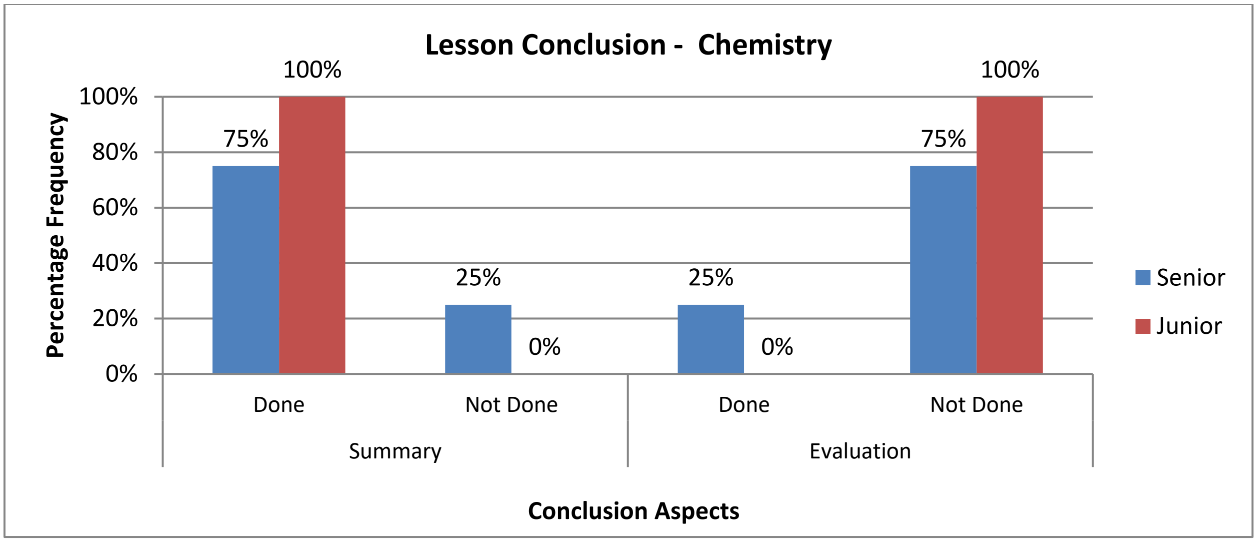


Figure 155: Lesson Conclusion for Senior and Junior Chemistry

The disparities shown at senior level between the planning and implementation stages as regards to conclusion of lessons, on one hand, suggest that teachers did not give much attention to necessary aspects that constitute the closure of lessons. On the other hand, it might also have meant that teachers had challenges to interpret and correctly implement what they had planned. Further, in the lessons in which summaries done it was observed that the inclination towards positivism as teachers led learners into responding to closed ended questions which had no link with the lesson intent. It is important to give learners overt opportunities to give lesson overviews. At junior level the remarkable accuracy in implementing what was planned, is evidence enough that teachers had adequate content knowledge and pedagogical skills. However, the complete none planning and evaluation of lessons might suggest that teachers thought evaluation cannot be done immediately at the close of the lesson but rather afterwards. In order to remedy this situation teachers are encouraged to participate in CPD activities. These CPD activities should not only include emphasis on the roles of both teachers and learners during the conclusion stage but also what constitutes summary and evaluation aspects.

d) Computer science

Figure 157 shows results on the lesson conclusion aspects for Computer Science at both senior and junior levels. The findings indicated that 60% of the lessons at senior level were not summarised while all the lessons (100%) at junior level were summarised. Regarding evaluation, there were only 40% of the senior lessons and 50% of the junior lessons were teachers considered this aspect.

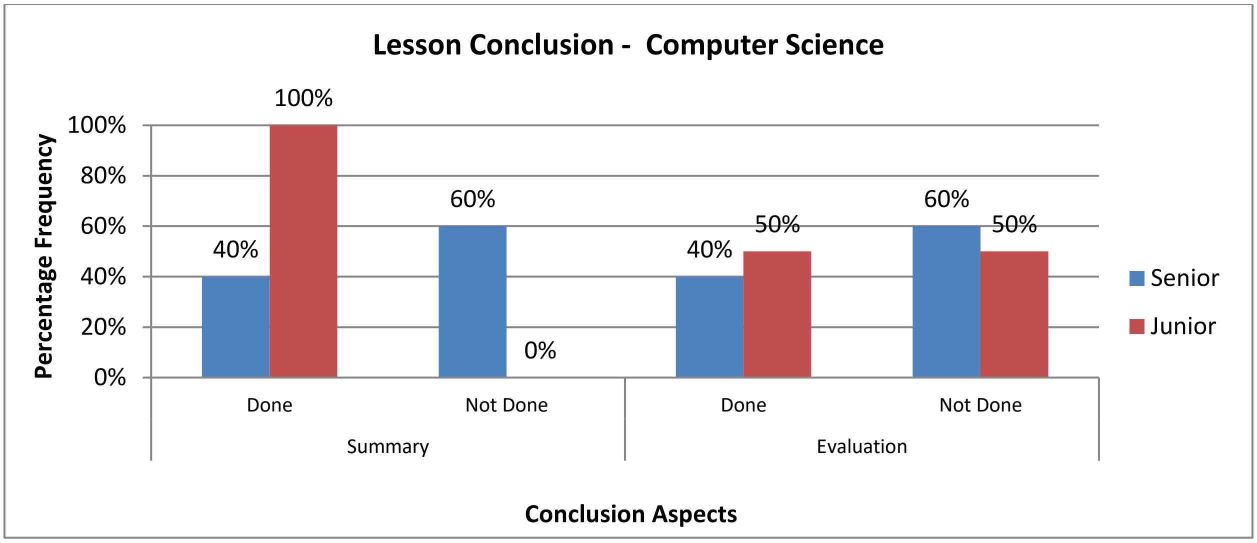


Figure 156: Lesson Conclusion for Senior and Junior Computer Science

The contributing factors to what the results indicate could be many but the major one might be the inability by teachers of Computer Science to prepare and document when and how the ending of the lessons should be done. Without these plans from the teacher there are greater risks of ending the lesson abruptly resulting in either no conclusion or haphazardly addressing just one of the components of it leaving learners wondering what the lesson was about and perhaps why it was taught. In order to minimize such chaotic ending of lessons there is need for teachers to understand the importance of concluding lessons and how to conclude them in co-ordinated ways by first summarizing and thereafter evaluating.

e) Design & Technology

The Design and Technology results on lesson conclusion aspects at senior and junior levels are shown in Figure 158. The findings reveal that 67% and 33% of the senior and junior lessons were summarized respectively. Additionally, only 33% of senior and 17% of the junior lessons were evaluated leaving 67 % and 83 % of senior and junior respectively lessons not been evaluated.

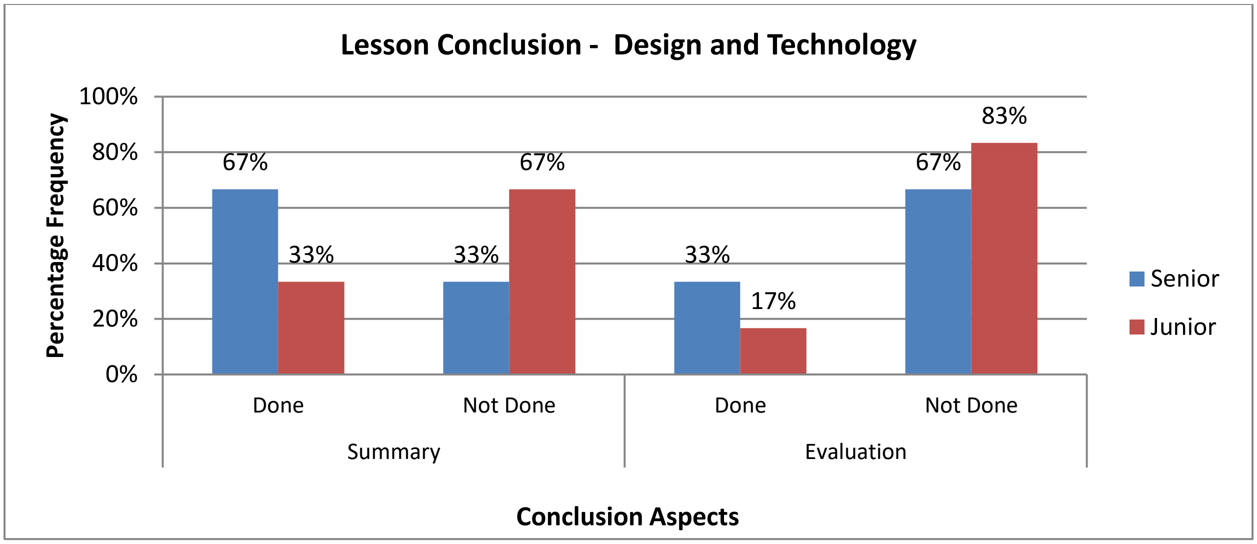


Figure 157: Lesson Conclusion for Senior and Junior Design and Technology

The more than average lessons summaries done at senior level is an indication that teachers were able to provide opportunities to check for understanding, emphasize key points, and tie up loose ends which was contrariwise at junior level. This means that some teachers had pedagogical challenges. This was evident also as what was planned, in some cases, was not implemented. At senior level there was thirty-three percentage points decrease from the lessons that had planned for summaries and those that implemented as can be decoded from Figure 79 on planning for lesson conclusion and Figure158 on lesson conclusion implementation. At junior level, 83% of the lessons had plans on how the lessons would have been summarised but only 17 % summarised the lessons at implementation stage. Further, the revelation that most of the lessons at both levels were not adequately evaluated becomes worrisome as it clearly indicates that the lessons intentions were not measured consequently the achievements of lesson outcomes were equally not considered. The reason for not evaluating lessons could be that teachers had insufficient delivery skill techniques on how to evaluate lessons. Additionally, there were disparities in what was planned and implemented as regards to evaluation of lessons. At senior level none of the teachers had indicated on lesson plans how they would evaluate the lessons, however, at implementation 17% of lessons were evaluated. The fact that teachers were able to appropriately evaluate lessons without having prior plans is indication that they did not take the teaching and learning process with the seriousness that it deserved. This was observed from the little time accorded to planning. Planning is critical as it may influence to some extent the quality of the lessons that would be delivered. Lesson evaluation is important as it helps check the effectiveness of a learning session. It also provides insights on whether or not the learning is effective and whether there would be need to reconsider the lesson concepts in successive lessons. Teachers are therefore encouraged to plan on how they would evaluate lessons and consequently evaluate the delivered lessons effectively. To do so, Design and Technology CPD activities need to be strengthened at all levels.

f) Hospitality & Tourism

Figure 159 indicates the results on summary and evaluation in Hospitality and Tourism at senior and junior levels. The findings revealed that all of the lessons at both senior and junior levels were summarised. None of the lessons at senior level were evaluated while all the lessons at junior level were evaluated.

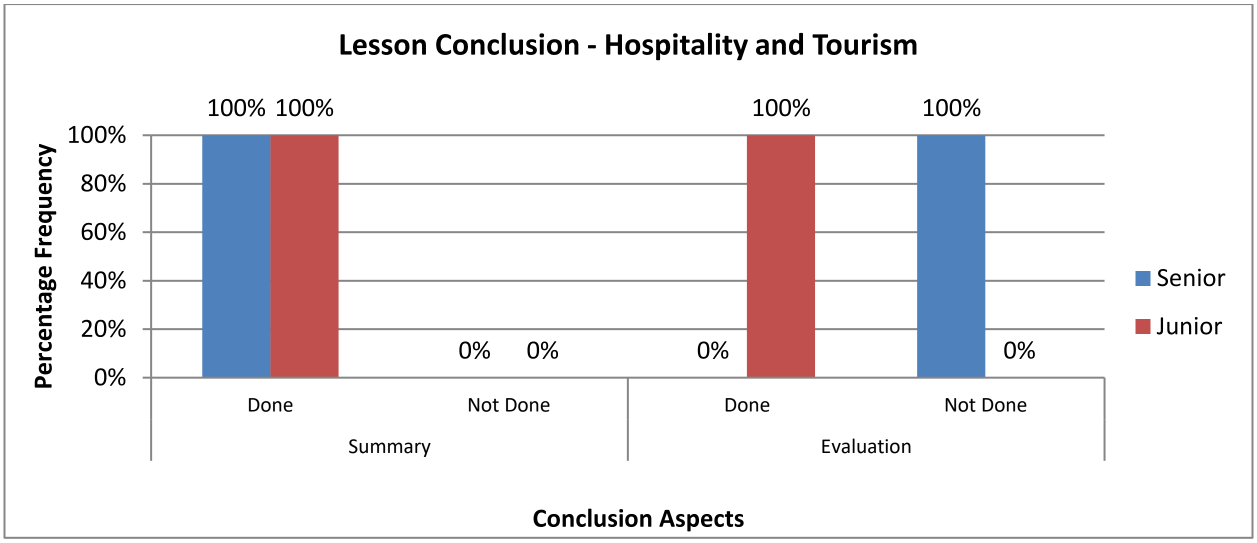


Figure 158: Lesson Conclusion for Senior and Junior Hospitality and Tourism

The wrap up of a lesson is the reminder that the academic activities are coming to an end and both the teacher and the learners will be looking forward to the review of the main aspects of the lesson in terms of content. Learners might want to express themselves on what they may have learnt, missed or what interests them more. Therefore, conclusion aspects of summarizing and evaluating lessons should both be planned for and actualized. However, disparities of these two conclusion aspects are a serious source of concern. For instance, despite summary not being planned for, at junior level, it was executed during delivery. Additionally, the non-indication of evaluation at planning stage but doing it during lesson delivery may indicate that teachers did not value it when planning for lessons. Further, failure by the teachers at senior level to evaluate the lessons was an indication that the evaluation was not taken seriously. This is so because although the word evaluation appeared on the predetermined lesson format sheet there was probably no realisation by teachers on its significance hence not paying attention to it both at planning and delivery stages. To this effect, teachers of Hospitality and Tourism will need to refocus the importance of lesson evaluation to the learning of learners by engaging in sustained CPD activities.

g) Mathematics

The Mathematics results on lesson conclusion aspects at both senior and junior levels are shown in Figure160. The findings disclosed that 60% and 67% of the senior and junior lessons respectively had summaries done. It was further observed that all the lessons at senior level and 67% of the lessons at junior level were not evaluated.

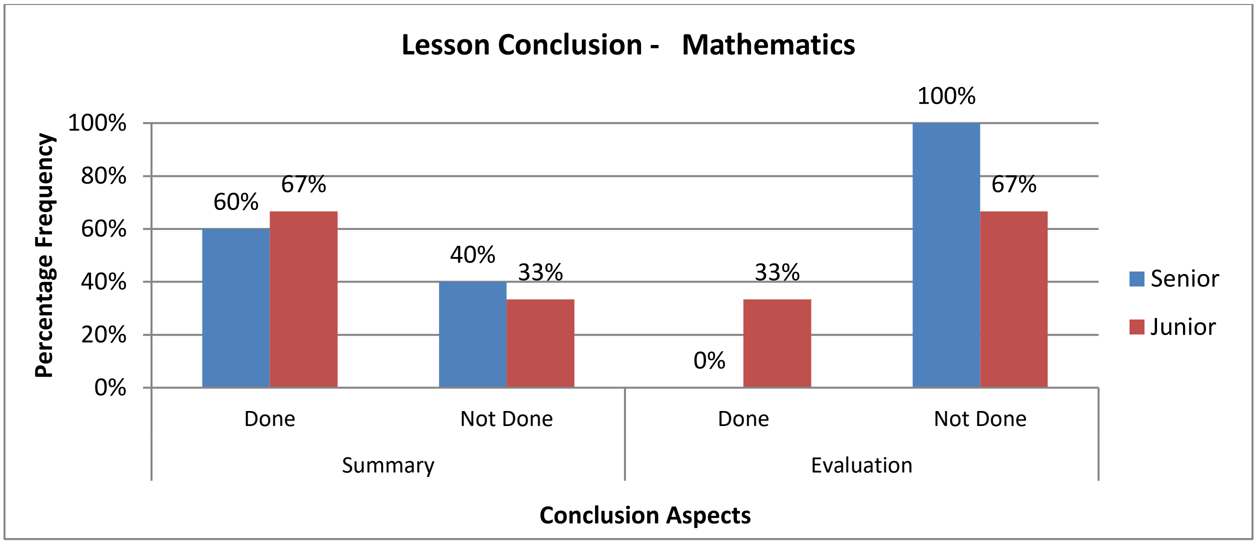


Figure 159: Lesson Conclusion for Senior and junior Mathematics

More than average lessons at both senior and junior levels had summaries done. The reasons for having more of the lessons summarized might be that some teachers had good pedagogical skills. This means that for these lessons' brief explanations on lesson intent and correction of identified gaps were addressed and therefore, the uncertainties in learners if any were cleared. Additionally, a shift was observed from the usual exercises as lesson closure activities to more meaningful ways of integrating central lesson ideas. Nonetheless, the complete absence of lesson evaluation at senior and the more than average lessons not evaluated at junior level raises concern as it suggests that assessment of the quality of teaching and learning was not done. The reasons for the lessons not being evaluated may be that some teachers did not understand the differences between summary and evaluation. Another reason might have been that teachers did not have adequate pedagogical skills as is evidenced by the disparities between what they planned to do at conclusion and what was actually executed at delivery (refer to Figure 85 under planning for lesson conclusion). The implication of not summarizing or evaluating lessons is that it would be difficult to know whether the lesson outcomes were achieved or not. It would further be difficult to determine which areas may need attention and revisiting. To alleviate these inadequacies, teachers' pedagogical skills can be enhanced through inclusion of pedagogical aspects in the capacity building activities at all levels.

h) Physics

Figure 161 shows results of lesson conclusion aspects in Physics at both senior and junior levels. The findings disclosed that at senior secondary level all the lessons were summarized but none were evaluated. At junior level 25% of the lessons had lesson summaries and evaluation done leaving 75% of lessons not being summarized and evaluated.

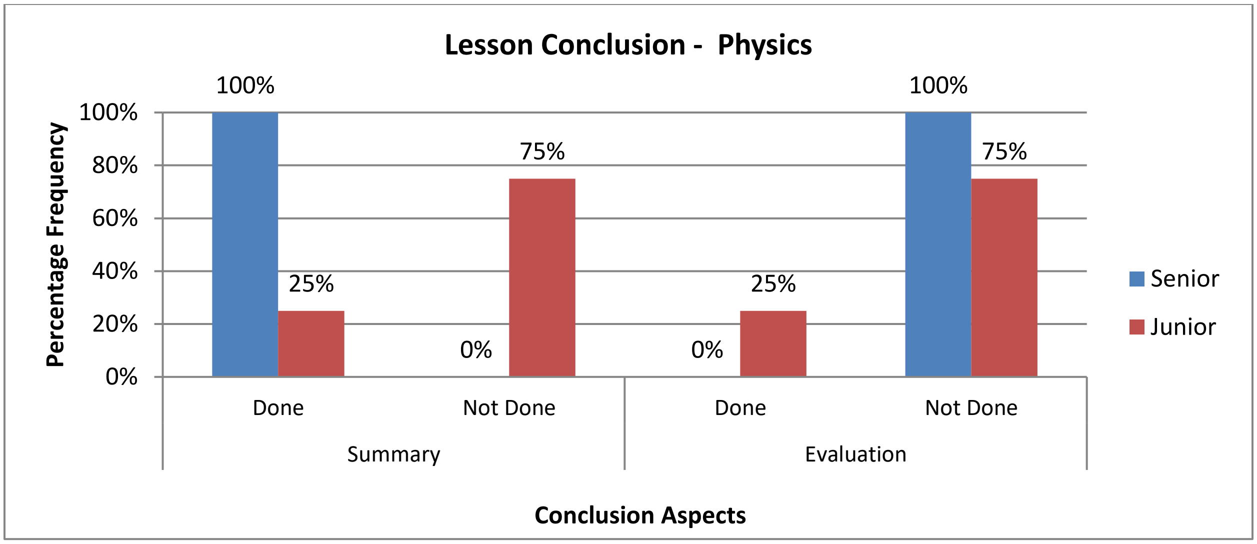


Figure 160: Lesson Conclusion for Senior and Junior Physics

On one hand, the 75% of junior lessons not summarized becomes of great concern as it means that in these lessons there may have been no reflection on the main aspects. The reason for this might have been that teachers had inadequate pedagogical skills as they could not execute what they had planned as lesson conclusions. For instance, 50% of the junior lessons had plans on how lessons were to have been summarized but only 25 % of the lessons were summarized at implementation. These existing disparities between what was planned for and executed are a clear indication of teachers' inadequacies in terms of pedagogical skills. Not summarizing lessons appropriately could render all efforts put in both preparation and execution in jeopardy. This is so because the content and discussion points might remain hanging and learners would have fragmented understanding of the concepts. As a result, learners may develop inconsistencies in the body of knowledge due to fragmented information which could not be organized at the closure of the lesson. On the other hand, the lessons not evaluated at both senior and junior levels are also of concern as it means that there was no assessment done. The implication of not evaluating lessons is that subsequent instruction would not be well informed as there would be insufficient or no information on the learners' limitations as regards to what was learnt. Therefore, to mitigate the inadequacies that teachers exhibited by not concluding lessons, CPD activities at all levels need to be strengthened and should include lesson delivery aspects.

4.1.12. Summary of Lesson Conclusion Aspects

Generally, it can be affirmed that conclusion might not be receiving the attention and due consideration during planning as well as the delivery stages.

The findings in Figure 162 of lesson conclusion aspects across all STEM subjects observed revealed that more than average of the senior (68 %) and junior (59 %) lessons had summaries done. On the contrary, less than average of the senior (21%) and junior (28%) had lesson evaluations done.

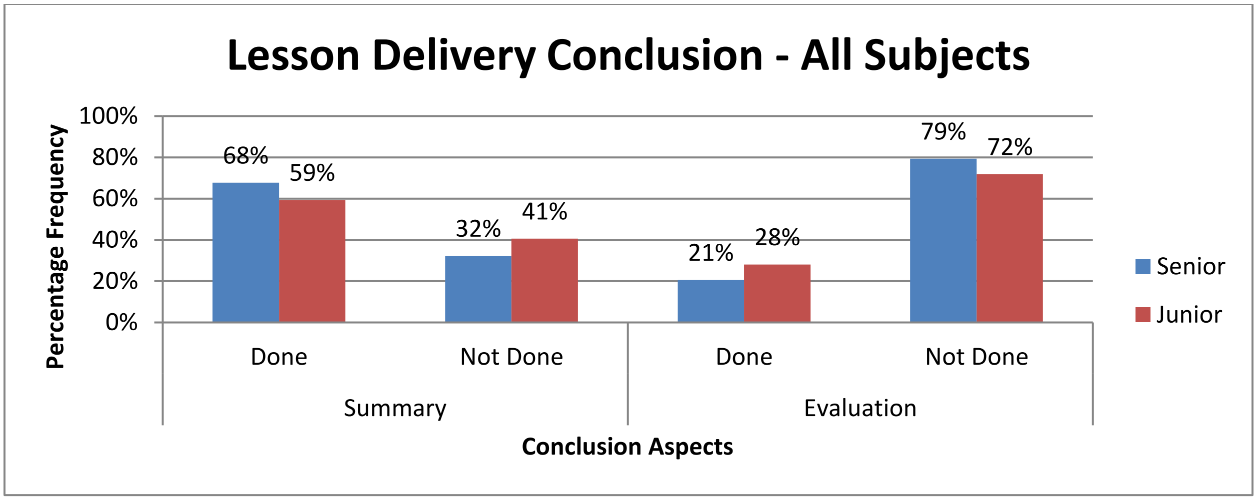


Figure 161: Lesson Delivery Conclusion - All Subjects

Closure is the step where you wrap up a lesson and help learners organize the information in meaningful contexts. Good lesson conclusions should comprise of a summary and evaluation. From the findings, it is apparent that some teachers had understanding of how to summarise lessons however, lesson evaluation aspects were a challenge for them. Arising from these findings, it therefore becomes imperative that teachers need to understand what constitutes lesson summary and evaluation. Other than this, they also need to develop skills on how to effectively conclude lessons. In lesson conclusion, it is not enough to simply say, "Are there any questions." A lesson conclusion is meant to help learners to better understand what they have learnt and provide a way in which to assess the learning. In order to provide effective lesson overviews and assessment of outcome attainment conclusions can be done by the learners, teachers or both. To ensure that lesson conclusion aspects are effectively planned for and implemented, teachers' content knowledge and pedagogical skills need to be enhanced. This can be done through strengthened subject communities of practice.

4.1.13. Teaching and Learning Aids Utilization

Teaching and learning aids are materials intended to help learners understand lesson concepts well, foster knowledge and skills acquisition. For the meaningful realisation of the afore-mentioned, learners should interact effectively with the TLAs. Additionally, TLAs help teachers in illustrating or reinforcing skills and concepts. In this regard, TLAs can be prescribed by either the teacher or the learners and if meant for a bigger audience they should be big enough for all to see and manipulate. Further, in order to be effective, TLAs should clearly be visible, practical and conform to real size estimations or proportions. There are several types of TLAs which include visual, audio and models. In lesson delivery there are various ways in which TLAs can support learning. In this perspective, TLAs will focus on utilization and who prescribed them. The results and analysis for the TLAs utilization across subjects and grades were:

a) Agricultural Science

Figure 163 shows results on the utilization of the TLAs in Agricultural Science lessons observed at both junior and senior levels. The findings indicated that the TLAs prepared during lesson planning were used during lesson delivery as indicated by the 100% at both senior and junior levels. All the TLAs were prescribed by the teacher as indicated by the 100% at both levels.

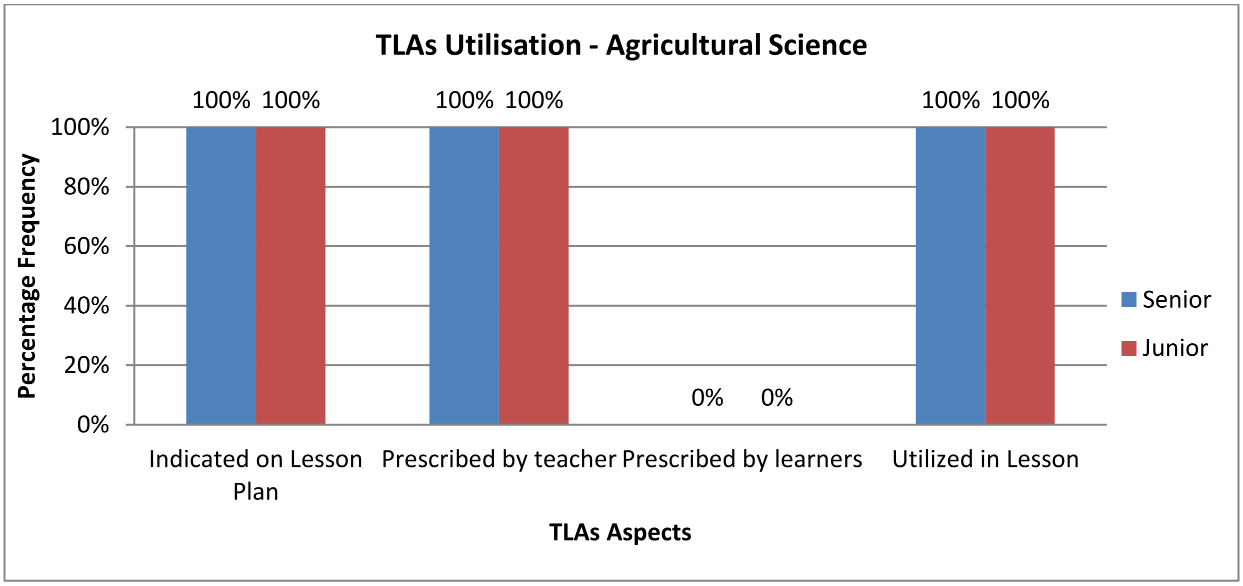


Figure 162: Lesson Teaching & Learning Aids Utilization for Senior and Junior Agricultural Science

At delivery, the use of all the TLAs which were prepared for the lessons entails that the course of lesson activities was in line with the planned ones. This could have been as a result of understanding curriculum pedagogical demands; therefore, the scheduled activities were interpreted in delivered lessons. The implication of using TLAs in lessons is that learners would be engaged in explorative activities that would ultimately support the attainment of desired knowledge and skills. In spite of the availability of TLAs they were not realistically utilized as learners did not effectively interact with them. Figure 164 shows captions of TLAs that were brought in the classrooms.

Figure 163: Teaching and learning Aid in Senior Agricultural Science Lesson

The caption on the left side of Figure 164 shows sprouting shoots as TLAs that were brought into class to support the learning of the concept on the understanding of conditions necessary for the germination of seeds. The mere presence of the sprouting plants was not appropriate in helping to support the acquisition of knowledge and skills on the aspect of germination. Similarly, in another lesson, a sprayer was displayed in a lesson whose outcome was to "*demonstrate the use of a hand sprayer"*. Learners did not at any point in the lesson use the sprayer thereby inhibiting the acquisition of the intended knowledge and skills. This ultimately impeded the realisation of the lesson outcomes.

Additionally, the fact that all TLAs in Agricultural Science lessons were prescribed by the teachers meant that learners were not provided with opportunities to be more creative as they should have been in their explorations. In as much as it is necessary for teachers to provide TLAs, learners must also be challenged to bring physical objects as aids to justify their ideas. The reason for this could have been that the framework of lesson activities was still in the positivist view. Therefore, the tasks given to the learners should prompt them to be innovative and bring aids as evidence to substantiate their views. To this effect, teachers of Agricultural Science need to engage in intensive study of TLAs through Lesson Study in order to enhance up-scale their competences.

b) Biology

The results in Figure 165 shows the findings on the utilization of the TLAs in Biology lessons observed at both junior and senior levels. The results indicated that the TLAs prepared during lesson planning were used at lesson delivery as indicated by the 100% at both senior and junior levels. All the TLAs used were prescribed by the teacher as indicated by the 100% at both senior and junior secondary levels.

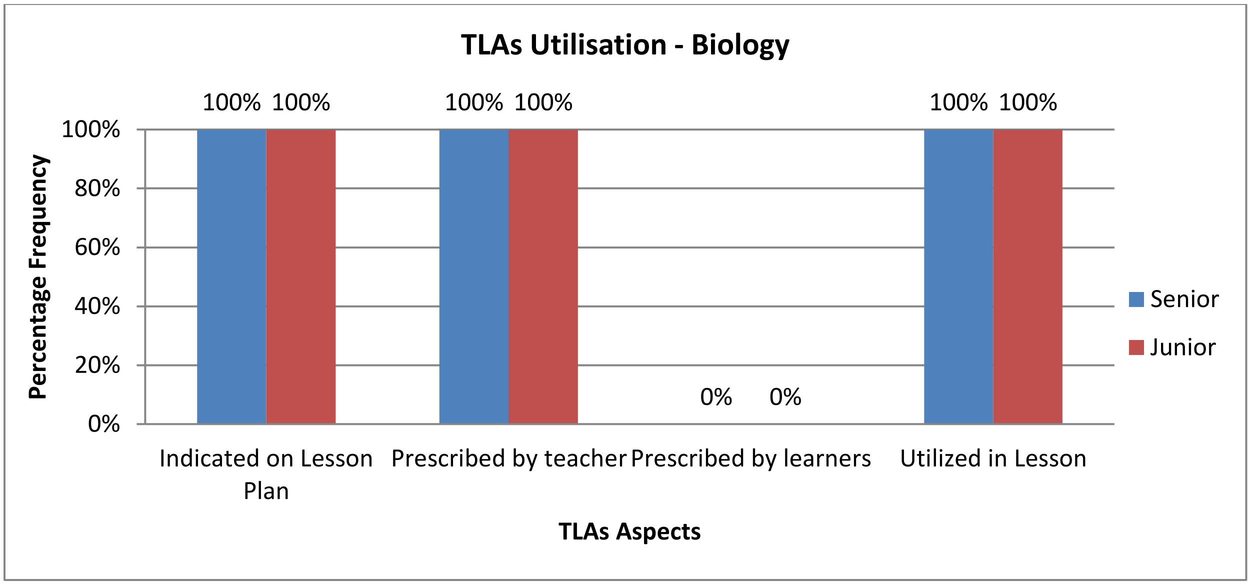


Figure 164: Lesson Teaching & Learning Aids Utilization for Senior and Junior Biology

In Biology, all TLAs prepared for the lessons were utilized during delivery of lessons. This might have been due to teachers' adequate understanding of the importance of role of TLAs in the learning process. The implication of this is that, there may be increased understanding of lesson concepts and enhancement of skills in learners. Despite having provided TLAs in the lessons, their use, in some cases as shown in Figure 154, were not appropriately applied.

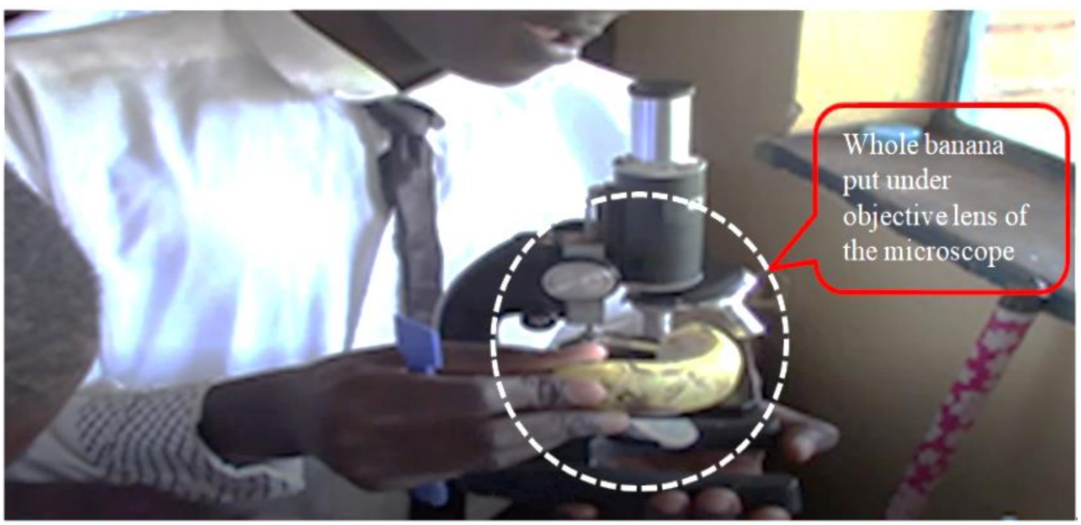


Figure 165: Utilisation of Teaching and Learning Aid in Senior Biology

In Figure 166 depicts the consequence of none frequent use of a Microscope as a TLA. At this stage of education delivery learners are expected to be acquainted with the use of this device. The reason might be that laboratories apparatus are kept under lock and key reserved for examination use only. In order to remedy situations such as this, learners, learners should be given frequent opportunities to interact more with the TLAs so that they familiarise themselves with the functionalities of devices. Additionally, teachers as facilitators of learning need to be proactive in identifying the challenges learners may be facing as they interact with the TLAs in the process of learning. This will enable the teachers to easily reinforce and clear misconceptions and errors arising from the interaction of learners with the TLAs. It is therefore recommended that, teachers need to strengthen their pedagogical skills and content knowledge through customised CPD activities.

c) Chemistry

Figure 167 shows results on the utilization of the TLAs in Chemistry lessons observed at both junior and senior levels. The results indicated that the TLAs prepared during lesson planning were used at lesson delivery as indicated by the 100% at both senior and junior levels. Further, all the TLAs used were prescribed by the teacher as indicated by the 100% at both senior and junior secondary levels.

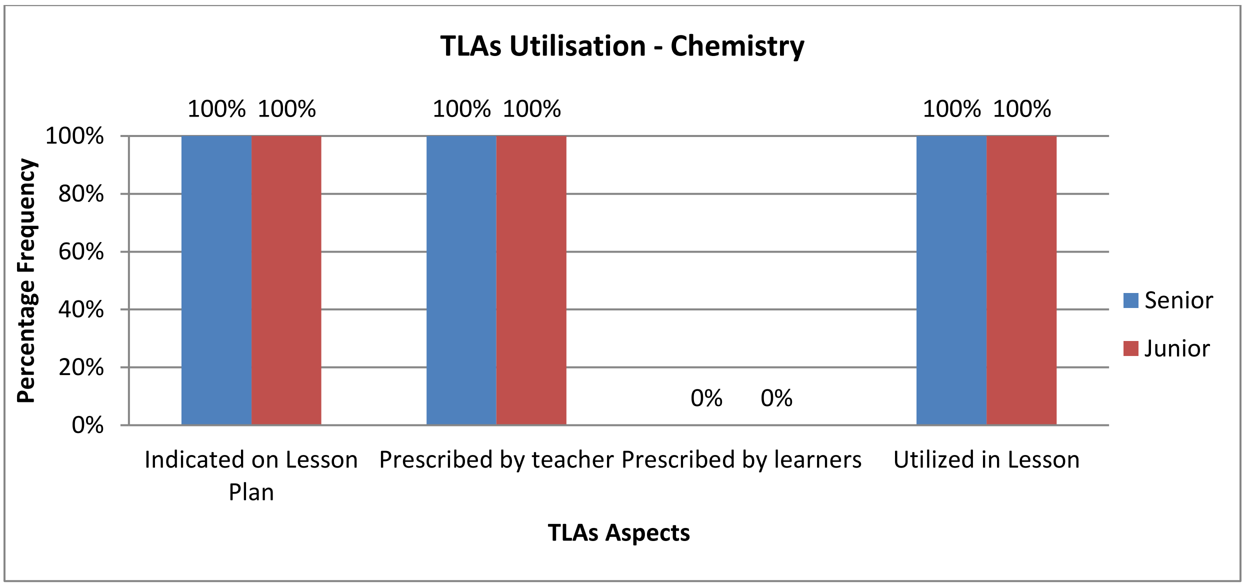


Figure 166: Lesson Teaching & Learning Aids Utilization for Senior and Junior Chemistry

In Chemistry, all TLAs prepared for the lessons were utilized during delivery of lessons. This insinuated that the delivered lesson activities were in line with the planned lesson activities. This might have been as a result of the teachers understanding of STEM curriculum implementation demands. This may imply that the lesson experiences would be meaningful as the TLAs would support the learners' conceptual understanding. However, the Chemistry TLAs used were mostly conventional. Cases in point amongst others included:

"Beakers, chemicals, potassium permanganate powder, laboratory equipment"

The list shows some TLAs in Chemistry lessons observed. STEM teaching and learning, should often involve use of conventional and non-conventional TLAs. The implication of only using conventional TLAs would be that learners would be denied of a wider range of context specific learning opportunities which are significant in everyday life. To be more effective TLAs need to be context specific so that they are meaningful to the learners. In order to provide aids that would be meaningful it is critical to intensively study them and this can be done individually or through intensified subject specific professional development activities. Further, all the Chemistry TLAs were prescribed by the teacher. The reason for this could be that TLAs were hastily prepared leaving the teachers with inadequate time to formulate activities that will foster learners' inputs in the preparation of TLAs.

d) Computer Science

Figure 168 shows results on the utilization of TLAs in Computer Science at both junior and senior levels. The findings indicated that all the lessons had indicated the TLAs to be used and those aids were utilized during delivery at both junior and senior levels. It was further revealed that, at both junior and senior levels, the TLAs were prescribed by the teachers.

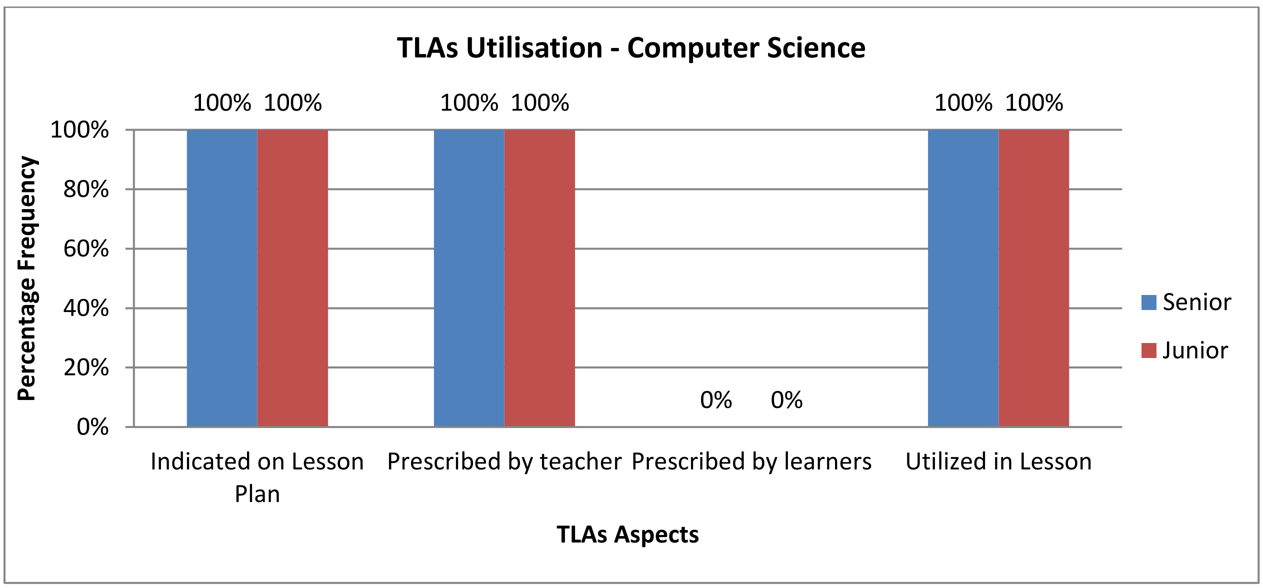


Figure 167: Lesson Teaching & Learning Aids Utilization for Senior and Junior Computer Science

In computer science, all TLAs prepared for the lessons were utilized during delivery of lessons. This meant that the lesson activities were in line with the pre-intended lesson activities. This could have been as a result of understanding Curriculum demands regarding the importance of TLAs in lesson outcome attainment. The implication of using teaching and learning aids in lessons was that learners were engaged in explorative activities that would ultimately lead to fulfilment of desired knowledge and attributes such as critical, creative, analytical and problem solving which are important in life. Additionally, all the computer science teaching and learning aids used in the classroom were prescribed by the teacher. The reason for this could have been that the outline of planned lesson activities was still in the positivist view. This might mean that learners could not have been provoked enough to foster critical, creative and analytical attributes which are expected in STEM learning. The other implication is that there were challenges of moving from positivism to constructivism as some teachers were still leaning on both the computer studies materials and non-STEM styles of teaching. However, despite the teaching and learning aids being prescribed by the teacher learners benefitted due to the way the lesson activities were scheduled as shown in Figure 169.

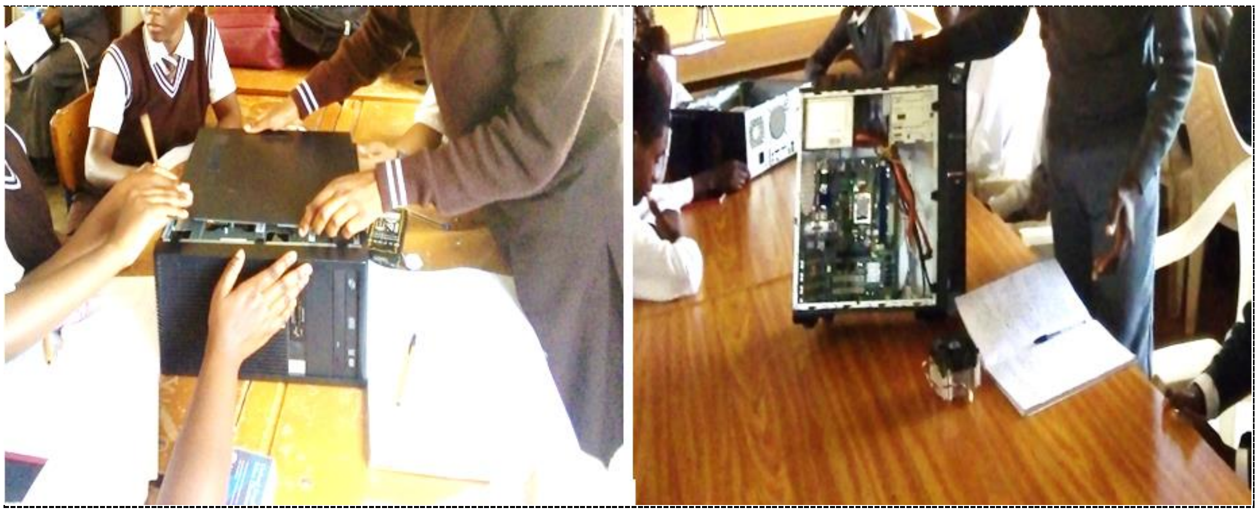


Figure 168: Computer Science Senior lessons in progress

From the above learners' involvement and engagement, it can be seen that the use of TLAs made them to be investigative and through the interaction with the aids their critical thinking and problem-solving skills were expected to be enhanced. Additionally, learners were able to express ideas with the help of the aids. Through exploring the TLAs as well as comparisons of different ideas, subject matter understanding and competences are enhanced. It is, therefore, recommended that teachers should continue exchanging ideas through CPD activities.

e) Design & Technology

The Design and Technology lessons results regarding the use of TLAs are shown in Figure 170. The findings indicate that all the TLAs prepared during lesson planning were used at lesson delivery as indicated by the 100% at both senior and junior levels. Additionally, it was also observed that all the TLAs used at both senior and junior levels were prescribed by the teachers.

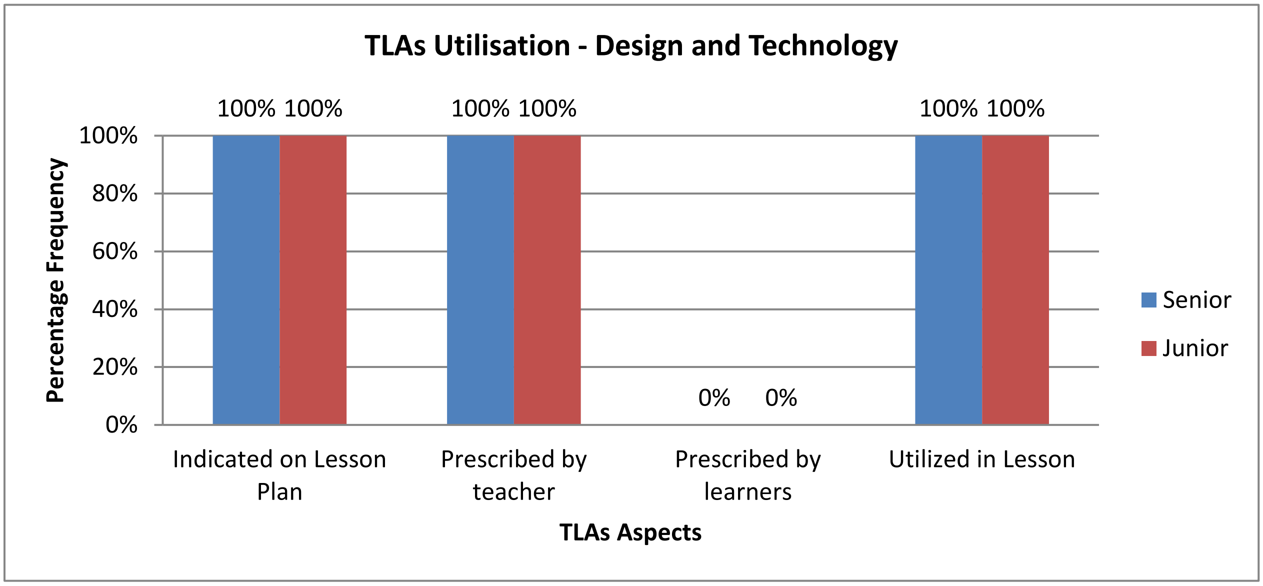


Figure 169: Teaching & Learning Aids Utilization for Senior and Junior Design & Technology

The extensive use of the planned TLAs suggests that teachers understood curriculum demands of producing critical, creative, analytical learners who would be able to solve real life problems. To this effect, they used TLAs in order to facilitate the acquisition of knowledge and desired skills. Some lessons in which the TLAs raised curiosity and helped learners to concretize their learning are as shown in Figure 171.

Figure 170: Sample Case of Effective Planning for TLAs

From the captions it is apparent that learners not only interacted with the TLAs but also interacted amongst themselves through sharing ideas thereby reinforcing their thoughts and helping them to deepen their conceptual understanding. In some lessons the learning was supported by the use of ICT. The incorporation of ICT as TLAs is an important aspect in Design and Technology as it might help contribute positively in fostering the engineering aspect in STEM Education. Figure 172 shows how the use of ICT helped to expose learners' creativity and innovation in Graphic Communication as they designed advertisements.

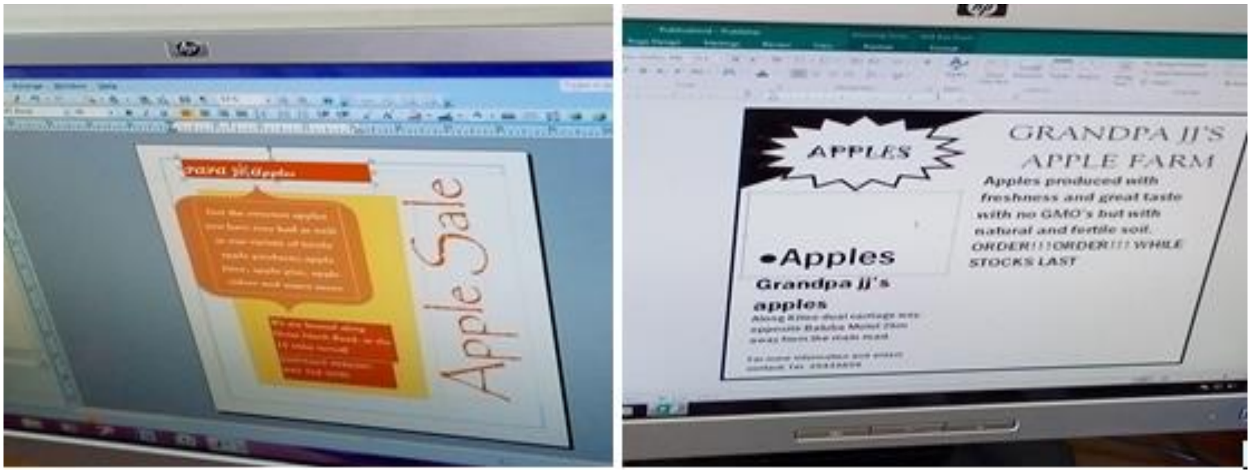


Figure 171: Sample Screen Shots of Learners' Advertisement Designs

The captioned sample screen shots showed learners' creativity as they designed advertisements in Graphic Communication. Through interaction with the ICT aids learners were able to participate, explore and think critically in order to create their designs. From these explorations, learners enhanced not only their conceptual understanding on the principles of graphic design (balance, alignment, repetition, proximity, contrast and space) but also their creative and manipulative skills. To further help learners deepen understanding STEM advocates for learner participation in the prescription of TLAs. However, this was not the case in the Design and Technology lessons observed as teachers prescribed the TLAs. For learners to participate in the provision of TLAs in the learning process the learning activities should be designed in such a way that they elicit learners to be innovative and bring aids as evidence to substantiate their views. Therefore, it is necessary for teachers of Design and Technology to have intensified study of teaching and learning materials at individual level and also through their participation in CPD activities at all levels.

f) Hospitality and Tourism

Figure 173 indicates results on the utilization of TLAs in Hospitality and Tourism at both senior and junior levels. The findings show that the lessons at both junior and senior levels had indicated the TLAs to be used during implementation. It was also revealed that the TLAs were prescribed by the teachers. Despite teachers prescribing the TLAs it was found that only the junior lessons used the TLAs during delivery. The lessons at senior level did not make use of the prescribed TLAs at all during implementation.

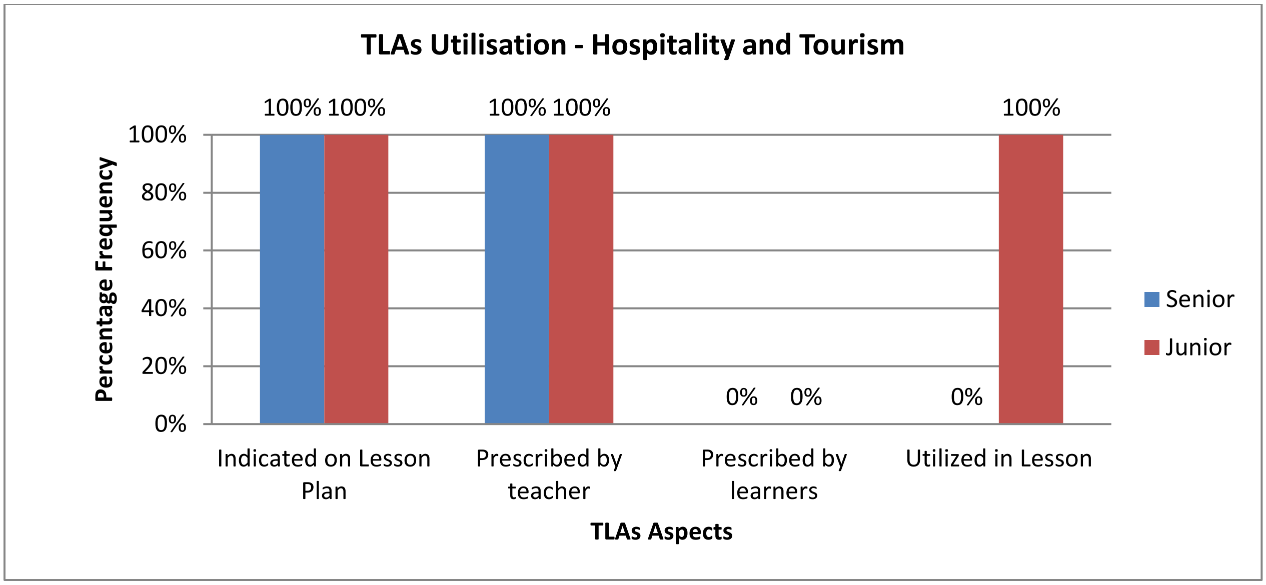


Figure 172: Teaching & Learning Aids Utilization for Senior and Junior Hospitality & Tourism

The non-use of the TLAs at senior level could have been as a result of not understanding curriculum pedagogical demands and inadequate pedagogical skills to execute and use planned for materials. The implication of not using TLAs in lessons is that learners would not gain the needed knowledge and competencies hence hindering the achievement of Curriculum expectations. One case in point is shown in Figure 174.

Figure 173: Sample TLAs brought to class but never used

The sources of nutrients, shown in Figure 174, were neither studied, touched nor used in any way despite being readily available in class during lesson delivery. To this effect, it may be suggested that their use was not planned for hence it became difficult to utilize them by both the teacher and learners. This occurrence may have been due to pedagogical and content knowledge incompetencies on the part of the teacher. Conversely, the prepared TLAs at junior level were all used during lesson delivery. This suggested that the delivered lesson activities were in line with the planned lesson activities. This could have been as a result of understanding Curriculum instructional demands therefore the planned activities were decoded in delivered lessons.

g) Mathematics

Mathematics lessons results regarding the utilization of TLAs during lesson delivery at both senior and junior levels are shown in Figure 175. The findings reveal that the TLAs prepared during lesson planning were used at delivery stage as indicated by the 100% at both senior and junior levels. It was also observed that at senior and junior levels 100% and 83% respectively of the TLAs used in the lessons were prescribed by the teachers.

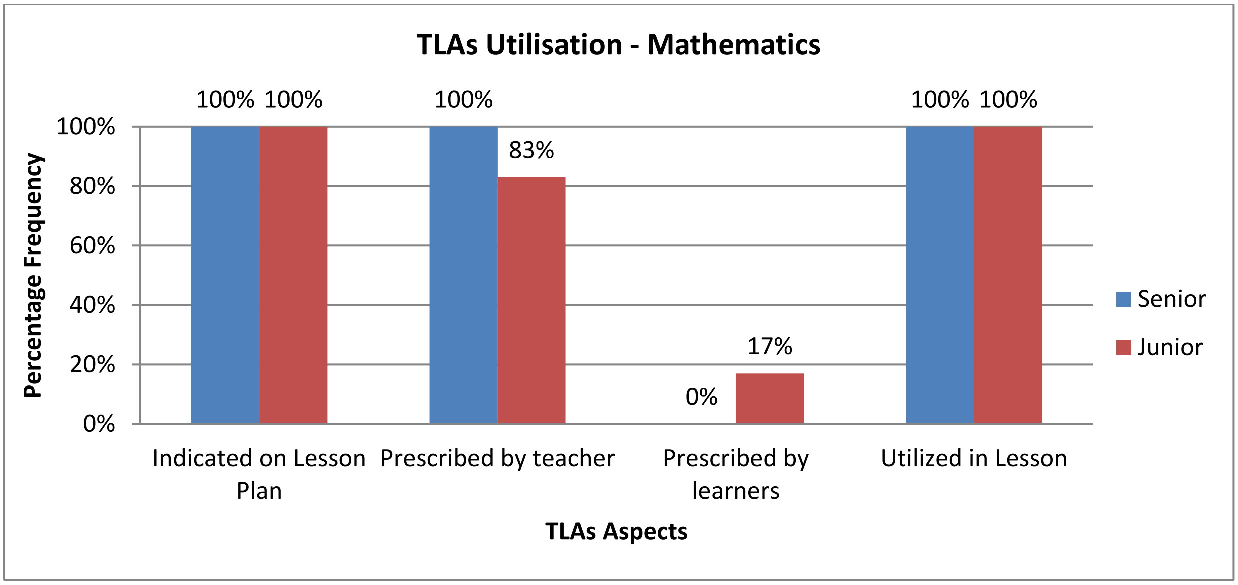


Figure 174: Teaching & Learning Aids Utilization for Senior and Junior Mathematics

Mathematics is an abstract subject and therefore, it can be learnt by means of tangible TLAs. The revelation that the TLAs planned for the lessons were all utilized during delivery of lessons entails that teachers had understanding of curriculum intentions and pedagogical skills. The implication of this is that the use of TLAs might facilitate the learning of Mathematics and ultimately assist in the understanding of lesson concepts. Additionally, having all and most of the teaching and learning aids at senior and junior level prescribed by the teachers respectively might suggest that teachers may not have created learning opportunities for learners to fully explore. This is a clear indication that teachers are still deep rooted in positivism as opposed to constructivism. The implication of this is that learners may not entirely acquire the expected knowledge and skills.

Using TLAs should provide opportunities to access content from a different vantage point in order to understand concepts better. To make learning effective, learners need to interact with various TLAs. The different TLAs used during the observed mathematics lessons included "*Work cards, chalk, charts, metre ruler, desks, exercise books, worksheet, black board, drink, guava, biscuit*". From this list it is clear that there was limited variety of TLAs used in Mathematics. To ensure effective learning, more tangible aids could have been provided or better yet learners themselves should have made some TLAs as a justification to substantiate ideas. This guarantees better retention of subject matter.

h) Physics

Figure 176 shows results of the TLAs used in the observed Physics lessons at both senior and junior levels. The findings disclosed that the TLAs prepared during lesson planning were used at delivery stage as indicated by the 100% at both senior and junior levels. Further, it was observed that all the TLAs used in both senior and junior secondary lessons were prescribed by the teacher as indicated by the 100%.

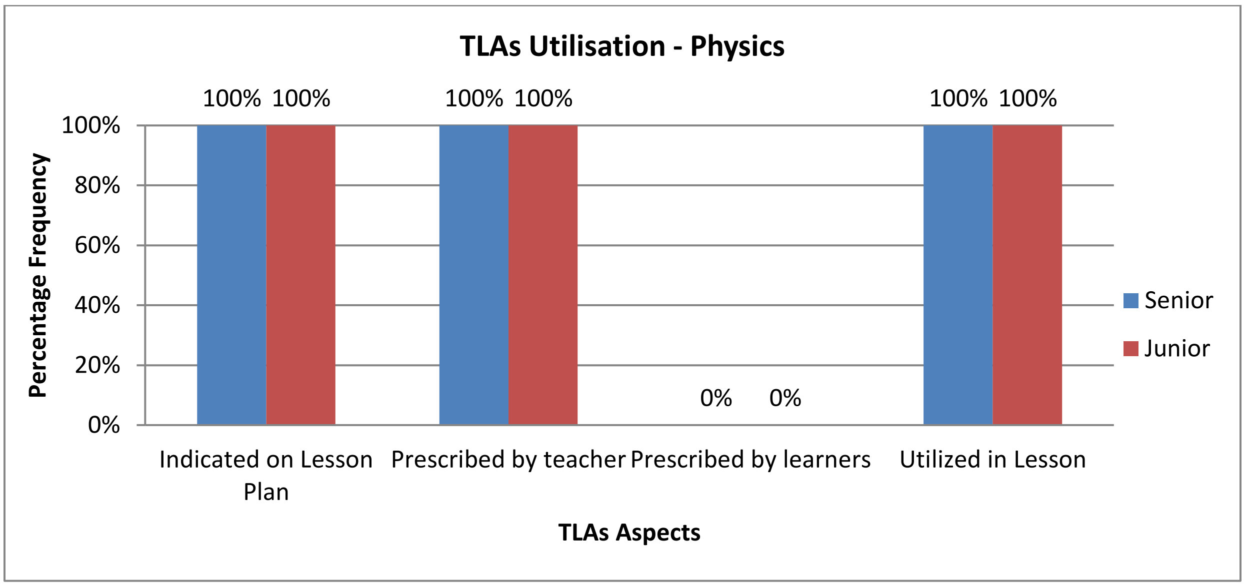


Figure 175: Teaching & Learning Aids Utilization for Senior and Junior Physics

A lesson is more effective and useful to learners when teaching and learning is done with the help of things that can be seen, heard or touched. Learners must be provided with opportunities to interact with TLAs in order to ensure understanding of lesson concepts and achieve lesson outcomes. The revelation from the findings that all TLAs organized for the lessons were utilized during delivery indicates that teachers had suitable instructional knowledge. Therefore, it was easy for them to consider the use of TLAs in lessons in order to facilitate effective and efficient learning. The implication of this might be that learning experiences would be concretized as there would be facilitation of learners' content understanding and concept formation through the interaction with TLAs. In order to facilitate learning varieties of TLAs that appeal to different senses should be used. However, Physics lessons did not make use of wide-spread TLAs especially Information and Communication Technology (ICT) tools. This could have been as a result of the schools abiding to rules of by non-use of ICT gadgets by learners. Another reason might have been non creativity on the part of teachers to plan and use ICT tools. The implication of the none use of ICT as a tool during lesson delivery would be that learners would trail behind in obtaining ICT literacy skills which are requisites in STEM Education. In this age ICT should be incorporated in the teaching and learning of Physics as they help enhance skills necessary in daily life due to high technology scientific advancements.

In as much as the planned TLAs were utilised, their prescription by the teachers may suggest that positivist traits were still at play. This denotes that teachers, even now, regarded themselves as the foremost source of knowledge. The reason for this may be that there are still challenges in becoming accustomed to constructivist approaches. The implication of having all the TLAs prescribed by teachers is that learners may not have the opportunities to be creative, innovative and think critically. This may deprive them of fundamental attributes that they would need for their advancement. Therefore, teachers are encouraged to continue sharing ideas through intensified CPD activities.

4.1.14. Summary of TLAs Utilisation for all the STEM Subjects

Figure 177 show the results of the summary of utilisation of TLAs for all the STEM subjects at both senior and junior levels. The findings indicate that all the subjects at both senior and junior levels had lesson plans showing the TLAs to be used during lesson delivery. Additionally, all the TLAs at senior level and 98% at junior were prescribed by teachers while 2% had prescriptions by learners. Further all the aids were utilised as planned at junior level as compared to 88% usage at senior level.

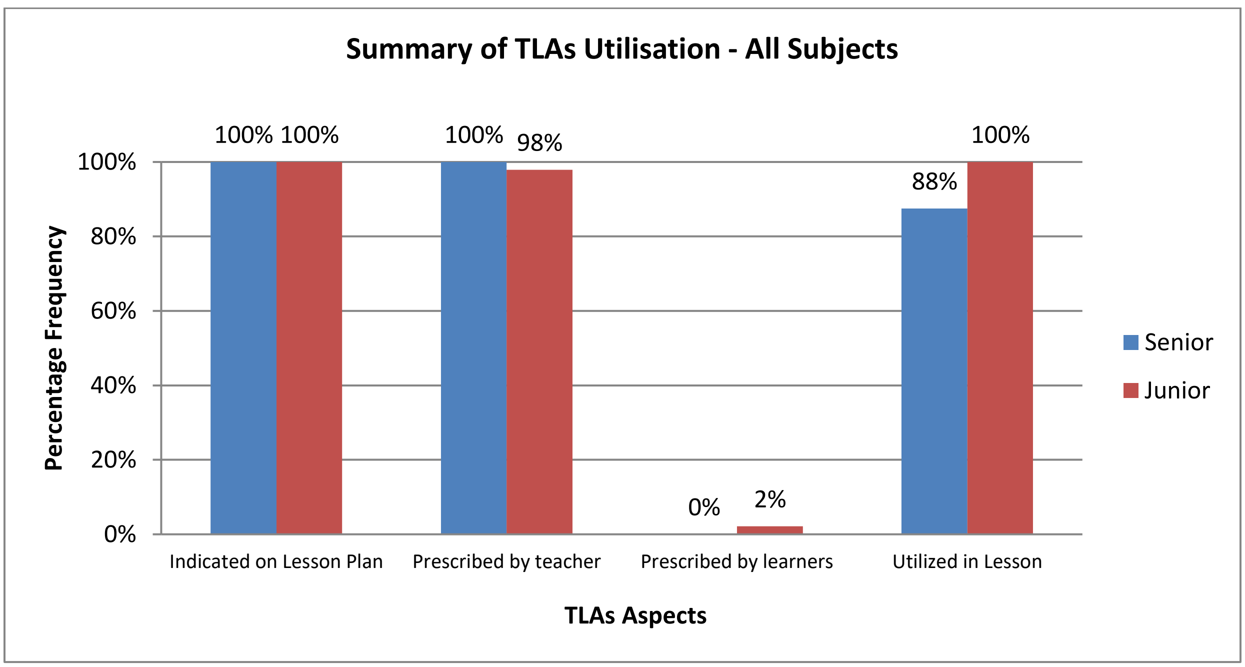


Figure 176: Summary of TLAs Utilisation for all the STEM Subjects

The revelation that only 2% of the TLAs were prescribed by the learners with more (98%) being done by the teachers becomes of great concern. This is so because learners were not given opportunities to think critically and be as creative as they should. The reason of having more TLAs prescribed by teachers could be that they were hurriedly prepared leaving no adequate time for formulation of activities that would foster learners' input towards the aids. Another reason may be that, teachers had struggles to adjust from positivism to constructivism. Yet another reason could be inability of teachers to be resourceful and creative. The implication of having TLAs being prescribed by the teachers is that, learning may be ineffective as learners would not be instigated to think critically, analytically and creatively. Nevertheless, there was impressive effort by the teachers to have planned and used the TLAs in the lessons. This could have been as a result of understanding curriculum instructional demands therefore the scheduled activities were interpreted in delivered lessons. In STEM lessons, the role of TLAs in the teaching and learning process cannot be understated. Therefore, careful planning and selection of TLAs should be given unceasing attention. To this effect, STEM teachers should engage in intensive study of TLAs through lesson study in both their respective subject areas and as integrated disciplines.

STEM Education - Curriculum Attainment

In STEM Education there are many aspects that can help establish whether the curriculum intentions have been attained. In the context of this research, STEM Education Curriculum attainment is discussed in terms of Scientific Skills, Research Work undertaken, Workbook Management and School-Based Continuous Assessment.

4.1.15. *Scientific Skills*

In the context of STEM Education in Zambia, Scientific Skills will refer to proficiencies needed to; study and apply Science, design and utilise Technology effectively, design and develop Engineering innovations, and solve Mathematics and apply Mathematical literacy. To this effect, STEM Education requires teaching and learning that analyses information, evaluates designs, reflects on thinking, synthesizes new ideas, and proposes creative solutions in order to produce independent critical thinkers. Additionally, STEM Education requires the ability to look at and propose solutions to problems through multiple approaches that are creative. In these creative approaches, mistakes and failed attempts are considered as positive experiences, offering opportunities for deeper learning. Further, STEM learners are expected to identify problems and consciously devise mechanisms to make sense of them as they are presented, and work productively to propose real and appropriate solutions. To achieve this feat, STEM learners require hands-on activities and active participation in the learning process to effectively solve problems. Learners are the drivers of solutions and therefore, should be asking questions, proposing ideas, generating and testing solutions, and making decisions based on data to understand how to refine ideas further.

This section highlights and discusses findings from the research focusing on Curriculum attainment by learners. At this stage the research sought to find out the extent to which the Curriculum intentions that were delivered during the teaching and learning process were attained by the learner. One of the ways of evaluating this is by observing and analysing Scientific Skills acquired and utilized by the learners during and after the learning process. In this survey focus was on five categories of Scientific Skills namely; Acquisitive, Organizational, Creative, Manipulative and Communicative skills. Each category had types of skills which were compared for compliance with the Curriculum intentions. The findings and discussions in Agricultural Science, Biology, Chemistry, Computer Science, Design and Technology, Hospitality and Tourism, Mathematics and Physics are shown below:

4.1.15.1.Agricultural Science

a) Acquisitive Skills - Agricultural Science

As regards Agricultural Science, Figure 178 shows the results on acquisitive skills for Junior level from the lessons observed in the survey. The findings indicated that listening, observing and inquiring were 100% clearly observed while searching as a skill was not observed and defining operationally was not applicable considering the type of lesson conducted. The other skills which include investigating, gathering data, researching and formulating hypotheses were either 50% clearly observed, not sure or not applicable at this level.

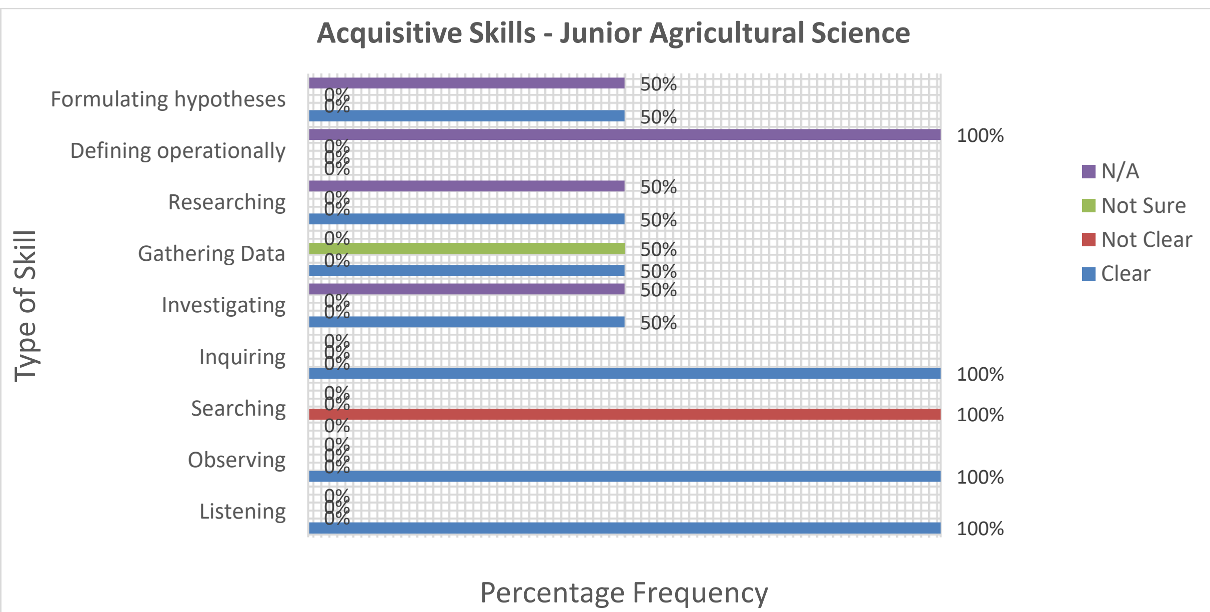


Figure 177: Acquisitive Skills - Junior Agricultural Science

At Senior level, 5 types of skills (listening, observing, searching, inquiring, and investigating) were clearly observed while the other skills (gathering data, researching, defining operationally and formulating hypotheses) were 50% either clear, not clear, or not applicable as shown in Figure 179.

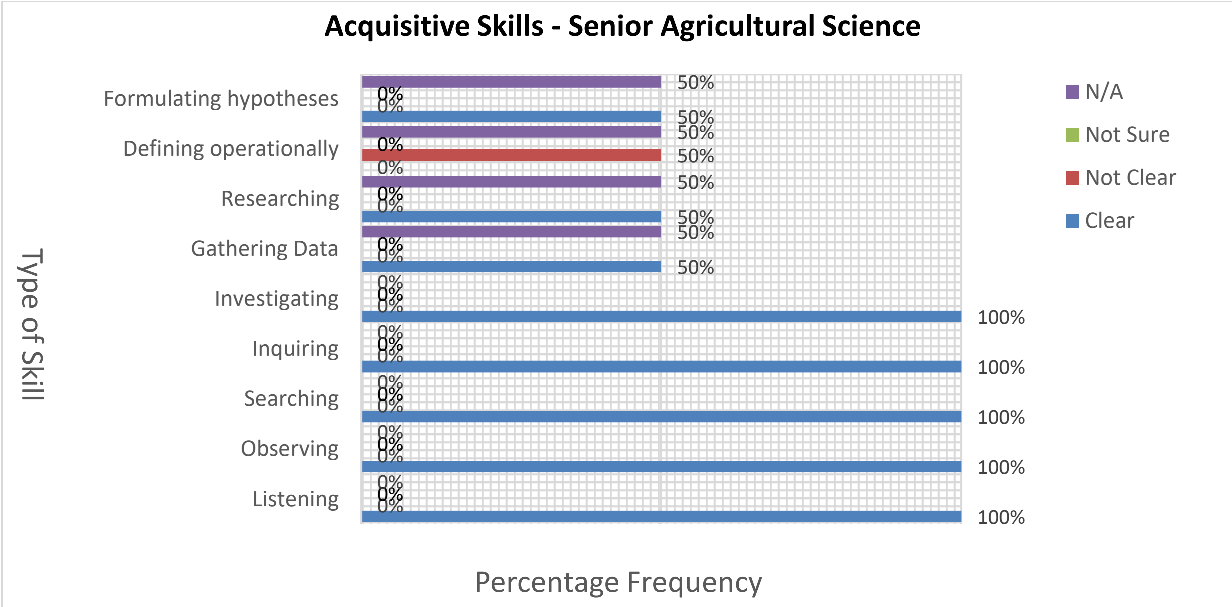


Figure 178: Acquisitive Skills - Senior Agricultural Science

The findings in the Agricultural Science lessons as regards to acquisitive skills showed that there was poor ability of lesson activities to foster acquisitive skills in learners at both Senior and Junior levels. This may be due to inadequate pedagogical content knowledge amongst teachers of Agricultural Science, thereby failing to prepare and deliver activities that would urge learners to engage actively and meaningfully during teaching and learning. A case in point is a lesson where the teacher brought to class the already sprouting shoots while the focus of the lesson was on conditions necessary for seeds germination (see Figure 164). Consequently, learners missed the opportunity to hypothesise because despite planning to bring seeds to class the teacher did not provide practical opportunities to subject the specimen to different conditions for investigation. Hence skills such as observing, gathering data and inquiring could not be developed in the learners. Learners were expected to formulate hypotheses on how the seeds would germinate under various conditions. The implication of this is that, the intentions of the Curriculum to produce critical, creative and analytical thinker could not be achieved. To this effect, there is greater need for teachers to enhance their pedagogical content knowledge for effective transfer and acquisition of skills through continuous involvement in professional development activities.

b) Organizational skills-Agricultural Science

Figure 180 shows results of 11 types of organisational skills at Junior level. The findings revealed that recording, evaluating and interpreting data were clearly observed while the rest of the skills in this domain were either 50% clear, not clear or not applicable.

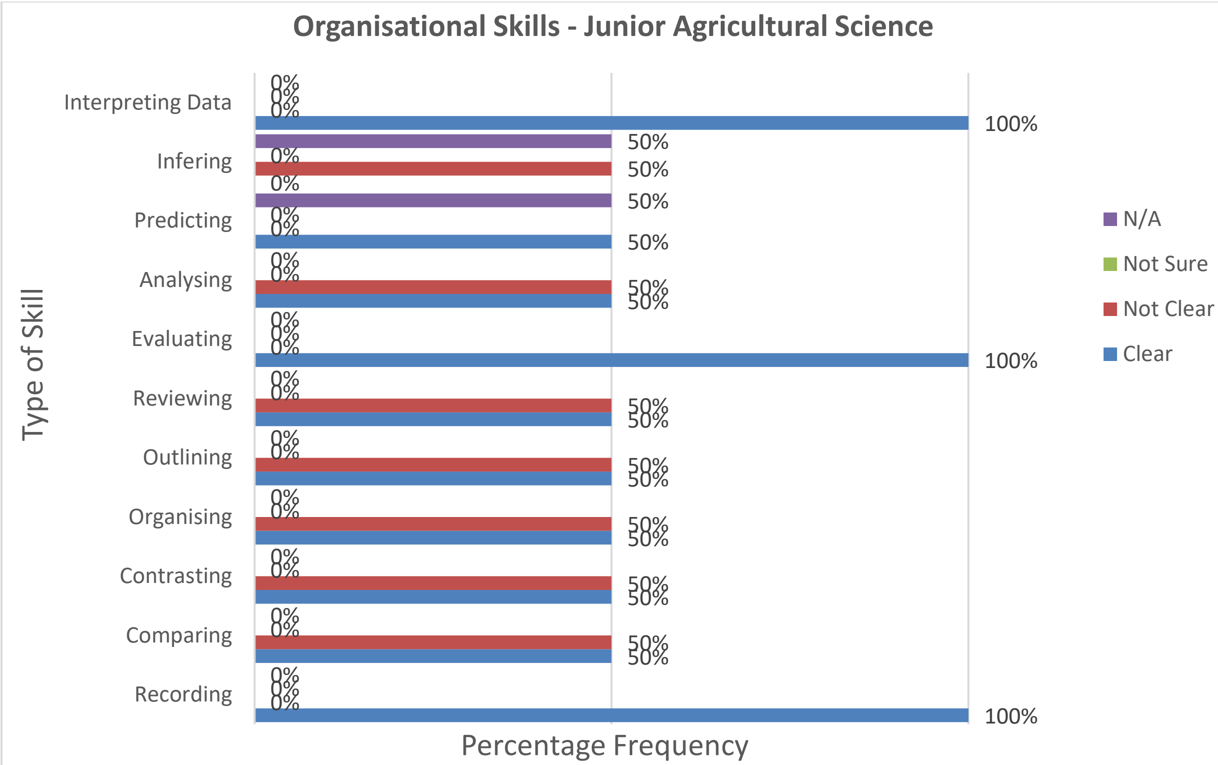


Figure 179: Organisational Skills - Junior Agricultural Science

At Senior level, 4 types of organizational skills (recording, contracting, organising and analysing) were clearly manifested during the lessons while the other skills (comparing, outlining, reviewing, evaluating, predicting, inferring and interpreting data) were 50% either clear, not sure or not applicable as shown in Figure 181.

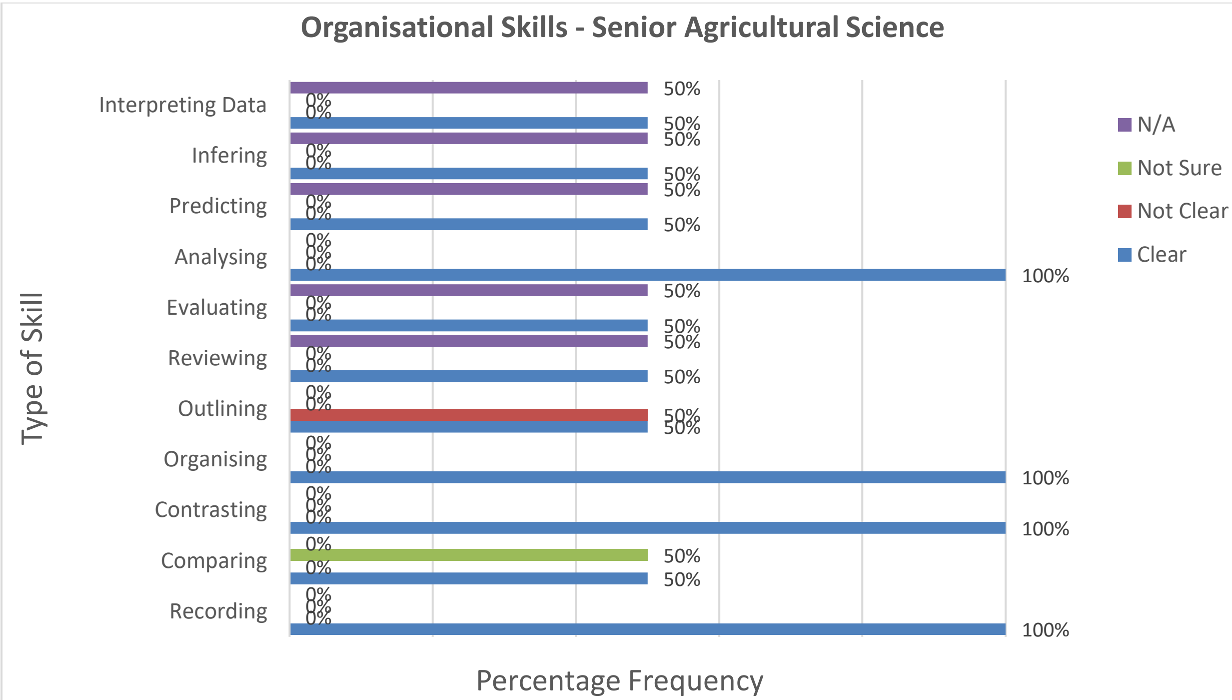


Figure 180: Organisational Skills - Senior Agricultural Science

The findings in the Agricultural science lessons as regards to organisational skills showed that there was poor ability of lesson activities to foster organisational skills in learners at both Senior and Junior levels. This might be the teachers had inadequate curriculum knowledge to prepare and deliver activities that would promote the acquisition of skills needed in the 21st Century. As indicated under the acquisitive skills, the learners were equally not given the opportunity to develop organizational skills to enable them compare, contrast and analyse the data they could have gathered during the learning process. This is due to the fact that they did not observe the process of germination under different conditions. The implication of this could be that, this category of scientific skills could not be developed in the learners which could lead to haphazard handling of data and misinterpretation of the curriculum intensions. Hence, there is need for teachers to develop pedagogical competences for fostering development of organisational skills in learners through involvement in regular CPD activities.

c) Creative Skills - Agricultural Science

Figure 182 shows results on creative skills at Junior level for Agricultural Science. The findings indicated that designing, inventing, sketching specimen and apparatus skills were not applicable in all the lessons observed at Junior level while in 50% of the lessons synthesising and formulating models were not clearly exhibited.

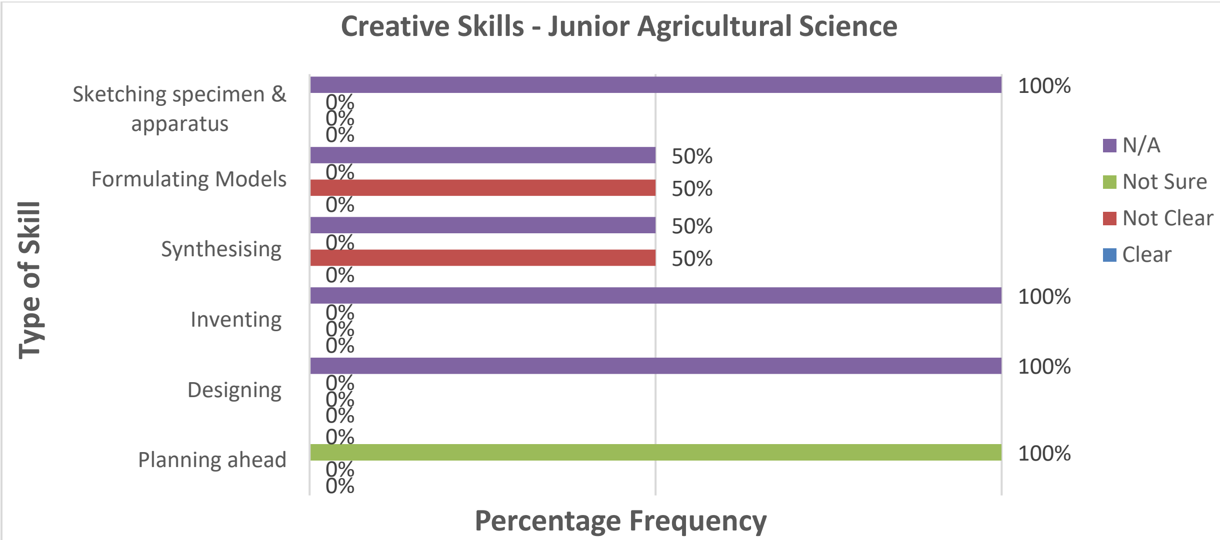


Figure 181: Creative Skills - Junior Agricultural Science

At Senior level, all the creative skills were rated not clear in 50% of the lessons and not applicable in the other 50% of the lessons observed as shown in Figure 183.

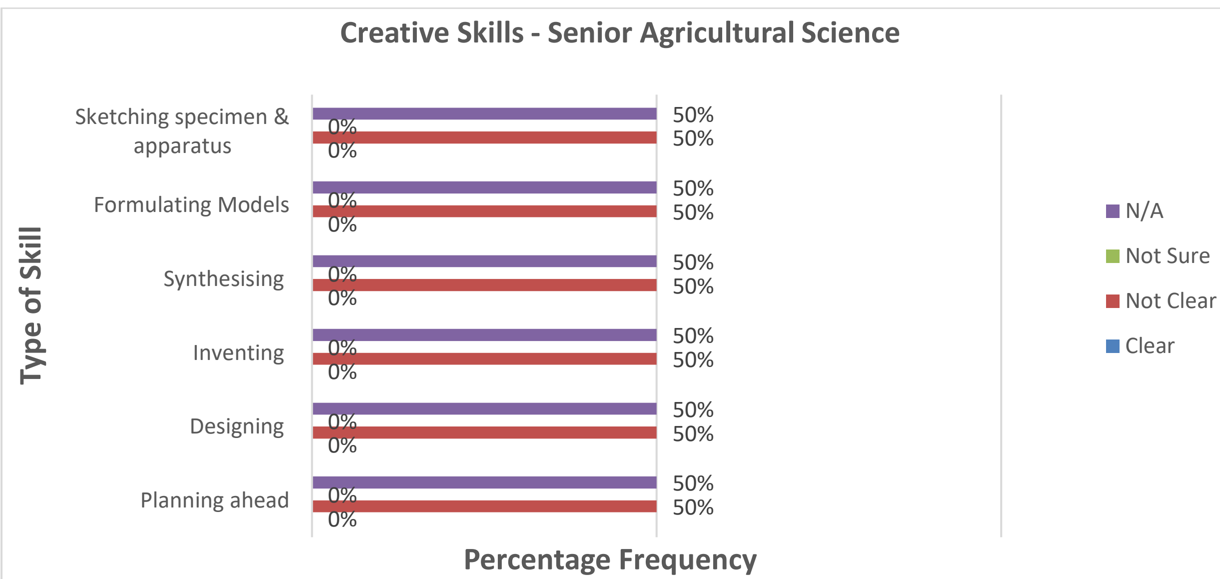


Figure 182: Creative Skills - Senior Agricultural Science

The findings in the Agricultural science lessons regarding creative skills showed that, none of the skills was clearly exhibited at both Junior and Senior levels. This may imply that the lessons in Agricultural Science inclined towards positivist approaches coupled with teacher centredness thereby obstructing learners' creativity potentials. This domain of skills is crucial for transformation of cognitive ideas into products. Additionally, teachers might not have adequate Curriculum knowledge to interpret its intentions, especially in the area of creative skills, and stir learners' creative interests and passion leading to suppression of skills exhibition. The implication of this could be that, the intentions of the curriculum would not be achieved, hence, the need for teachers to continuously involve themselves in professional development programmes.

d) Manipulative Skills – Agricultural Science

Figure 184 shows results on 8 types of Manipulative Skills for Agricultural Science lessons observed at Junior level. The findings indicated that in 50% of the lessons observed, demonstrating, controlling variable and handling specimen correctly & carefully were clearly displayed at Junior level while in the rest of the lessons these skills were either not clearly displayed or not applicable at all.

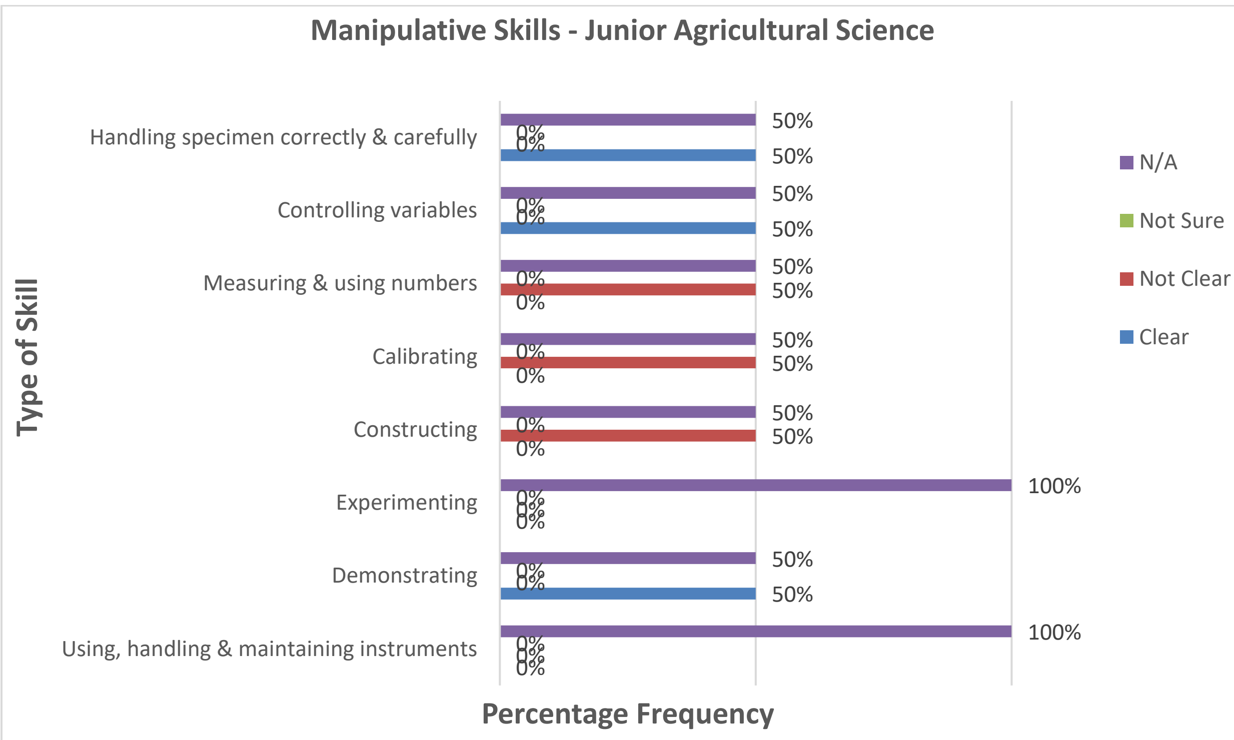


Figure 183: Manipulative Skills - Junior Agricultural Science

At Senior level, the skill of controlling variables was clearly exhibited in 50% of the lessons in Agricultural Science. The rest of the skills in this domain were either not clear or not applicable as shown in Figure 185.

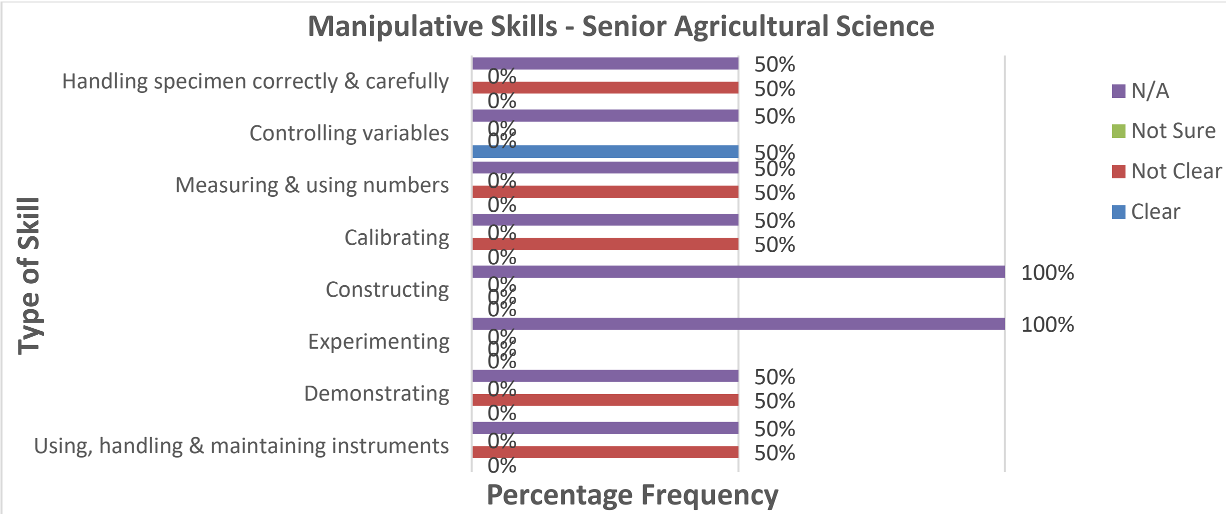


Figure 184: Manipulative Skills - Senior Agricultural Science

Manipulative skills involve the ability to use, handle and maintain instruments and apparatus carefully; they also involve ability to build or make something or form an idea by bringing together various conceptual elements. This category of skills is important for learners to develop higher order thinking skills. The Agricultural Science results as regards to manipulative skills for both Junior and Senior levels indicated that most of the lessons did not involve the activities that would bring out manipulative skills. This meant that the activities planned for fell short of strategies that would solicit effective engagement and exploration amongst learners. The reason for this might be that there was inadequate knowledge as to what should comprise lessons activities to bring out manipulative skills in the learners. The implication is that the intentions of STEM Agricultural Science Curricula may not be fulfilled when ideas from such lessons are implemented. It is, therefore, recommended that teachers should intensify on the use of demonstrations and experiments in order to ensure that learners' participation is existent. The hands-on experiences will improve the chances of learners' understanding the concepts and enhance the cognitive level at which they will be able to apply the knowledge and skills acquired.

e) Communicative Skills - Agricultural Science

Figure 186 indicates Communicative Skills results in Agricultural Science lessons at Junior level. Out of 9 types of communicative skills 7 of them were clearly observed in all the lessons while critiquing and graphing skills were observed only in 50% of the lessons. In the other lessons these skills were not manifested.

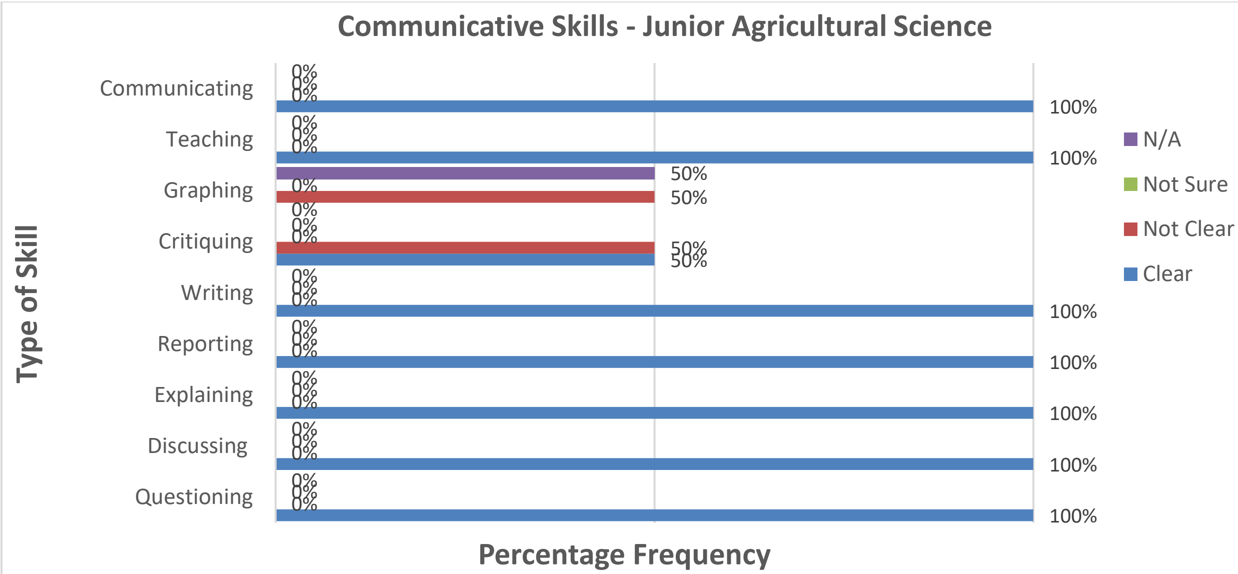


Figure 185: Communicative Skills - Junior Agricultural Science

At Senior level all the Communicative Skills were clearly exhibited in all the Agricultural Science lessons except for Questioning, Critiquing and Graphing as shown in Figure 187.

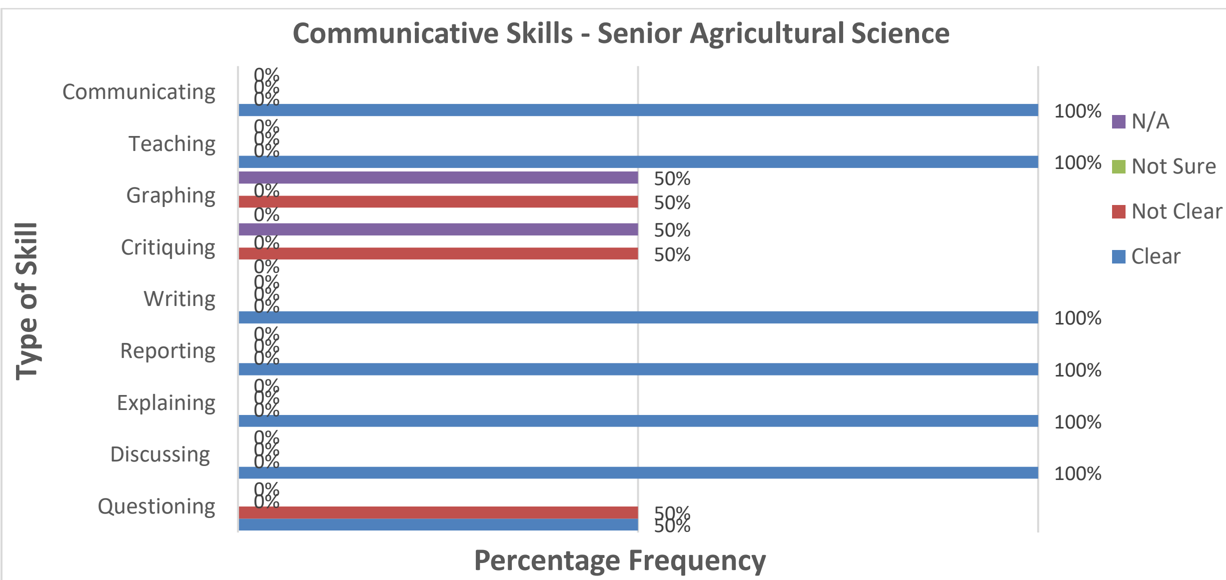


Figure 186: Communicative Skills - Senior Agricultural Science

The results indicate that, there was significant achievement in communicative skills for both Seniors and Juniors. This could have been that the learners were given chance to express themselves freely through discussions, questioning, explaining and writing. Learners communicated with both their peers and teachers through presentations and further contributions from the entire class. This facilitated the acquisition of the skills needed for the learner to be creative, innovative, critical thinker and problem solver. The implication of this is that the skills that the learners were expected to acquire and develop were planned for and hence the lessons yielded the desired outcomes. However, there is need to engage learners in Questioning and Critiquing skills as well. Teachers to continuously engage in professional development activities so as to positively impact on learners' achievement and also allow teachers to have an in-depth understanding of curriculum aspects and explore various ways of implementing the curriculum.

4.1.15.2. Biology

a) Acquisitive skills - Biology

Out of 9 types of Acquisitive Skills, listening, observing, searching and gathering data were clearly observed in all the lessons while the other skills were observed in 50% of the lessons as either clear, not clear, not sure or not applicable at Junior level as shown in Figure 188.

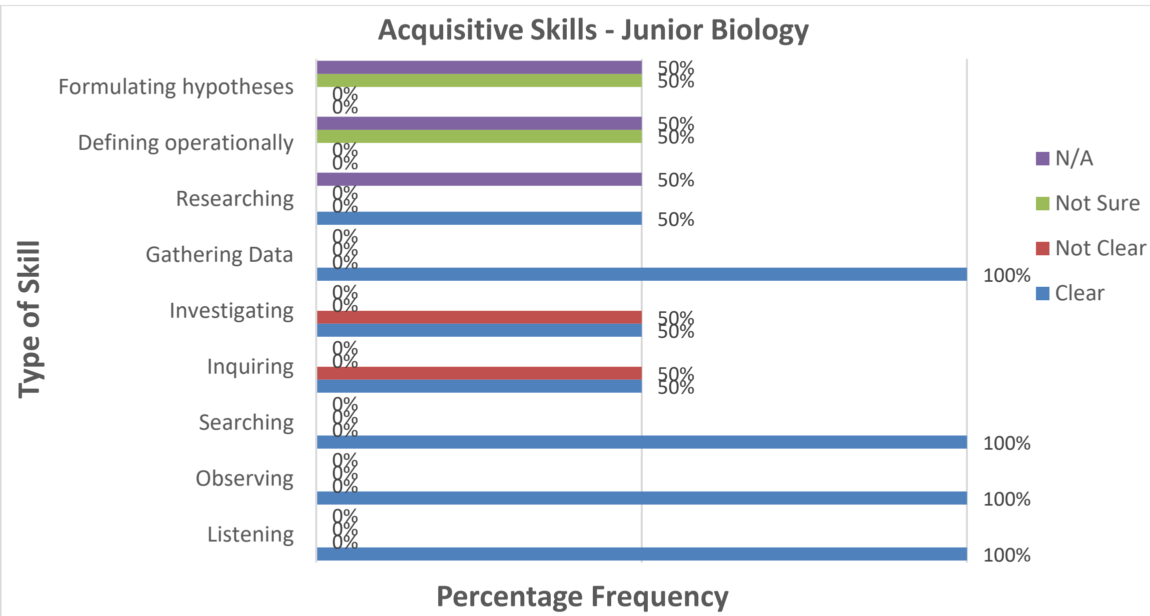


Figure 187: Acquisitive Skills - Junior Biology

At Senior level, 5 out of the 9 Acquisitive skills were observed in all the lessons, 3 skills were exhibited in 67% of the lessons and in 33% of the lessons only formulating hypotheses was observed. Figure 189 indicates the results of the Acquisitive skills as observed in Biology lessons at Senior level.

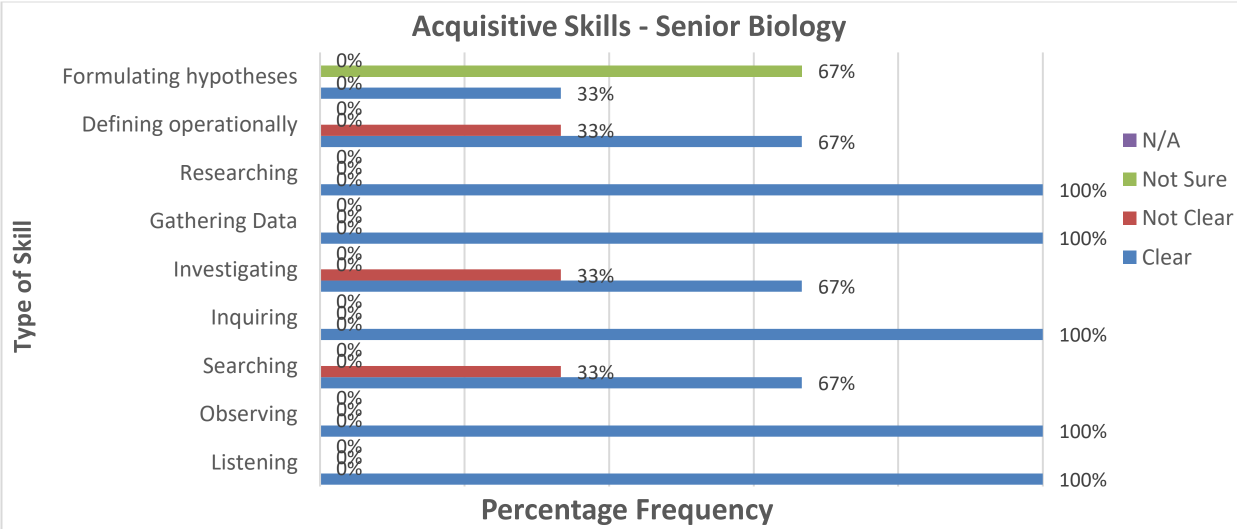


Figure 188: Acquisitive Skills - Senior Biology

As regards to Biology, the learners both at Senior and Junior levels considerably achieved Acquisitive Skills in conformity with the curriculum intentions. This could have been as a result of teachers understanding the curriculum intentions and so prepared and delivered appropriate strategies that helped to elicit Acquisitive Skills in learners. This could facilitate the development of Acquisitive Skills needed for national development. In order to help learners acquire all the Acquisitive Skills teachers need to continuously engage in professional development activities to enhance their knowledge of the curriculum so as to have improved preparation and delivery of lessons.

b) Organizational Skills - Biology

Figure 190 shows results on Organisational Skills for Biology lessons observed at Junior level. The findings indicated that Recording and Reviewing Skills were clearly exhibited in all the lessons while comparing, contrasting, organising and evaluating skills were observed in 50% of the lessons. The rest of the skills were not exhibited or showed not sure implying uncertainty.

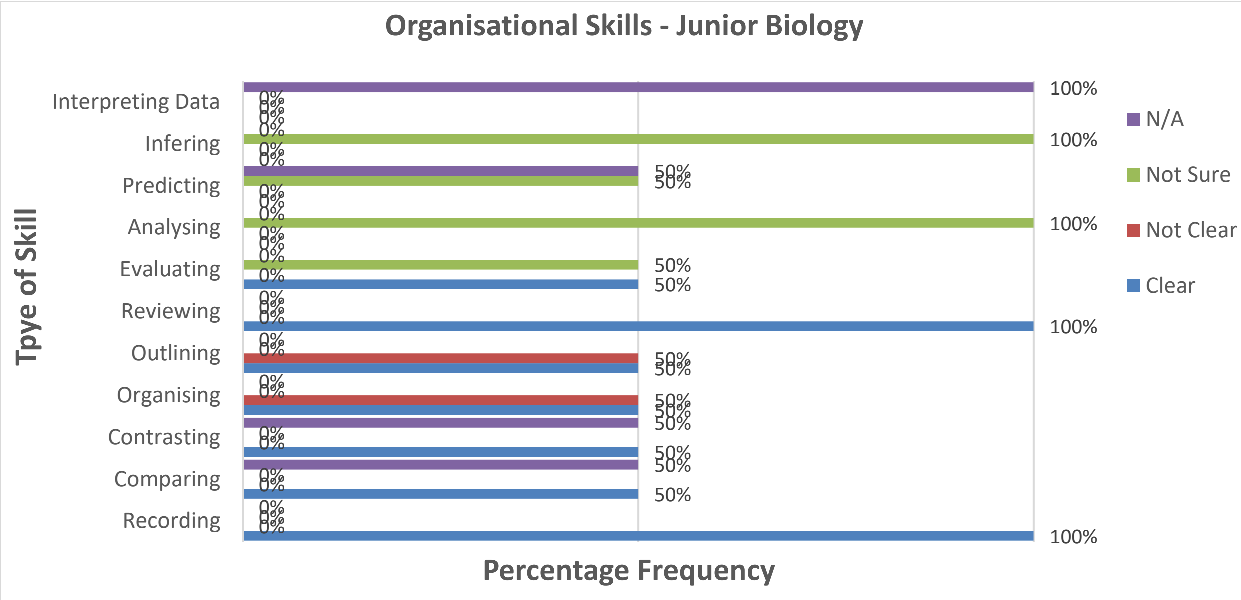


Figure 189: Organisational Skills - Junior Biology

At Senior level 6 of the Organisational Skills were clearly observe in all the Biology lessons, 4 skills were observed in 67% of the lessons while 1 skill (predicting) was observed in 33% of the lessons as shown in Figure 191.

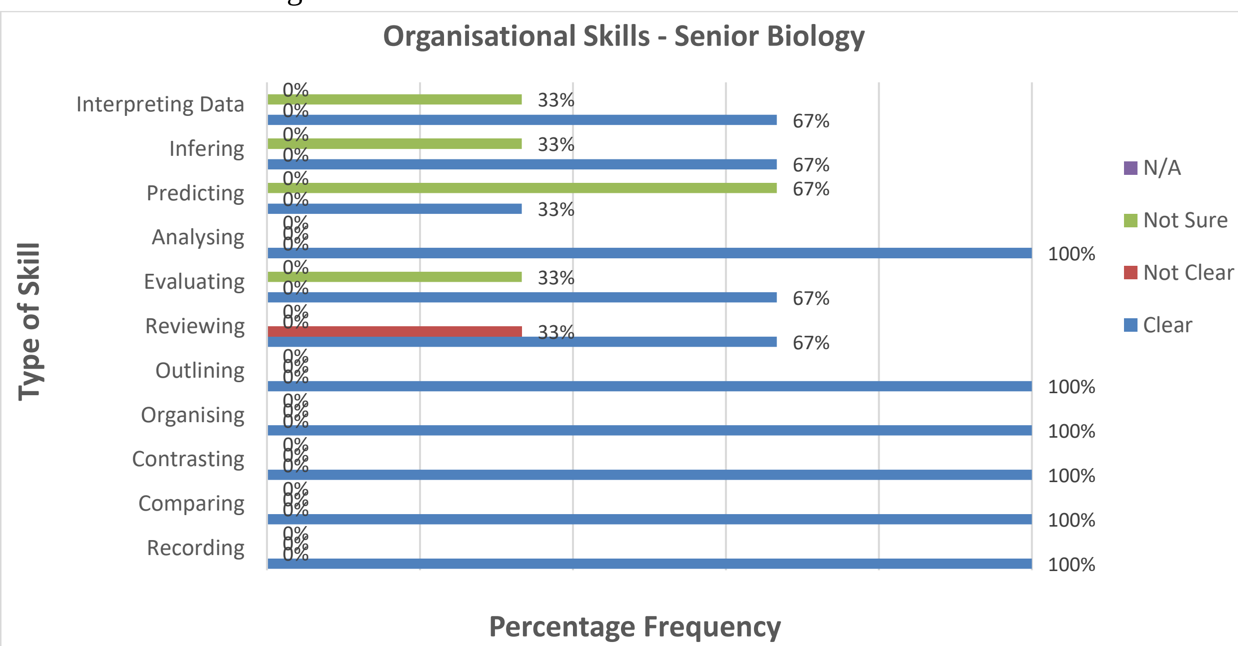


Figure 190: Organisational Skills - Senior Biology

As regards to Biology, the learners both at Senior and Junior levels considerably achieved organizational skills in conformity with the curriculum intentions. This could have been as a result of teachers understanding the curriculum intentions, thereby, prepared and delivered the lessons as intended. The learners were able to display Organisational Skills from the activities that were given. The acquisition of the Organisational Skills could help to understand the world as it is and be able to compare and contrast the data that they gathered as they carry out the tasks. However, for the results showing not sure the implication is that the skills involved require more attention on the part of the observer as they are intrinsic in nature. Therefore, more capacity building in form of CPDs and customised trainings are required.

c) *Creative Skills*

Figure 192 shows results on Creative Skills for Biology at Junior level. The findings indicated that none of the 6 types of skills were exhibited in all the lessons observed.

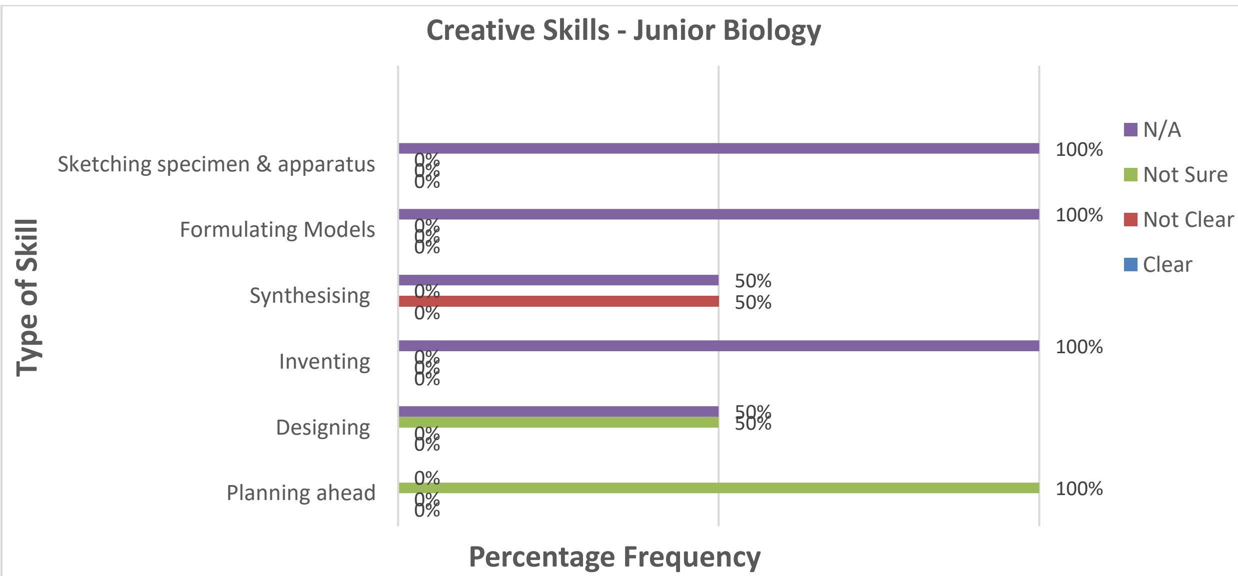


Figure 191: Creative Skills - Junior Biology

At Senior level, as can be seen in Figure 193, the most outstanding skill exhibited by learners was sketching specimen & apparatus which was clearly observed in all the lessons. Planning ahead and Synthesising were observed in 67% of the lessons while Designing, Inventing and Formulating models were exhibited in 33% of the lessons.

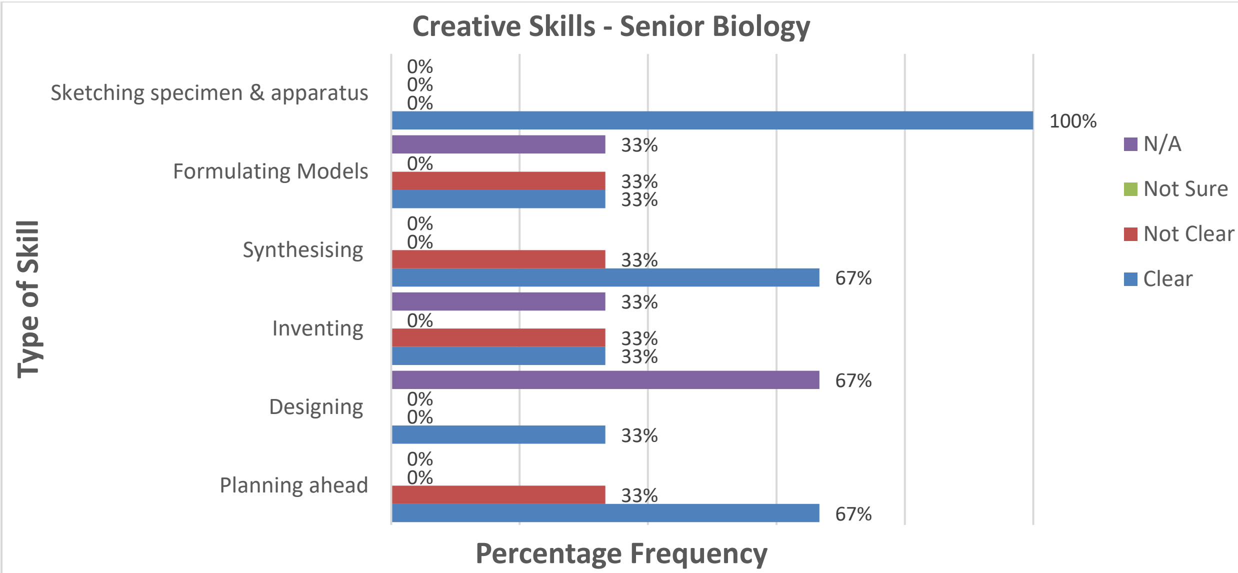


Figure 192: Creative Skills - Senior Biology

The findings in Biology lessons as regards to creative skills suggest that the activities prepared for learners were of poor quality which could not foster creative, innovative, critical thinking skills in learners at both Senior and Junior levels. The learners at both levels showed very limited acquisition of creative skills. This could have been that the curriculum knowledge amongst teachers was not adequately understood so as to prepare and deliver activities that would promote the acquisition of creative skills needed in the 21st Century. Creative Skills are a hallmark of Scientific Skills nerve centre through which the STEM Education theories are translated into visible products. Therefore, the poor results recorded in this domain become a source of concern as it poses a challenge in interpreting and attaining the STEM Education intentions. The implication of this could be that it would be difficult to come up with products if learners do not have creative skills. The ideas that learners accumulate end up as philosophies due to inadequate creative skills. It is therefore imperative that teachers plan and deliver lesson activities that stimulate creative skills development. In this vein strategies that foster the teachers' capacity to support learners need to be enhanced.

d) Manipulative Skills

Out of 8 Manipulative Skills in Biology, at Junior level, 3 skills (Using, handling & maintaining instruments, Experimenting and Handling specimen correctly & carefully) were observed clearly in 50% of the lessons while the rest of the 5 skills were either 50% not clear or not applicable. There was, however, uncertainty on constructing as a skill as shown in Figure 194.

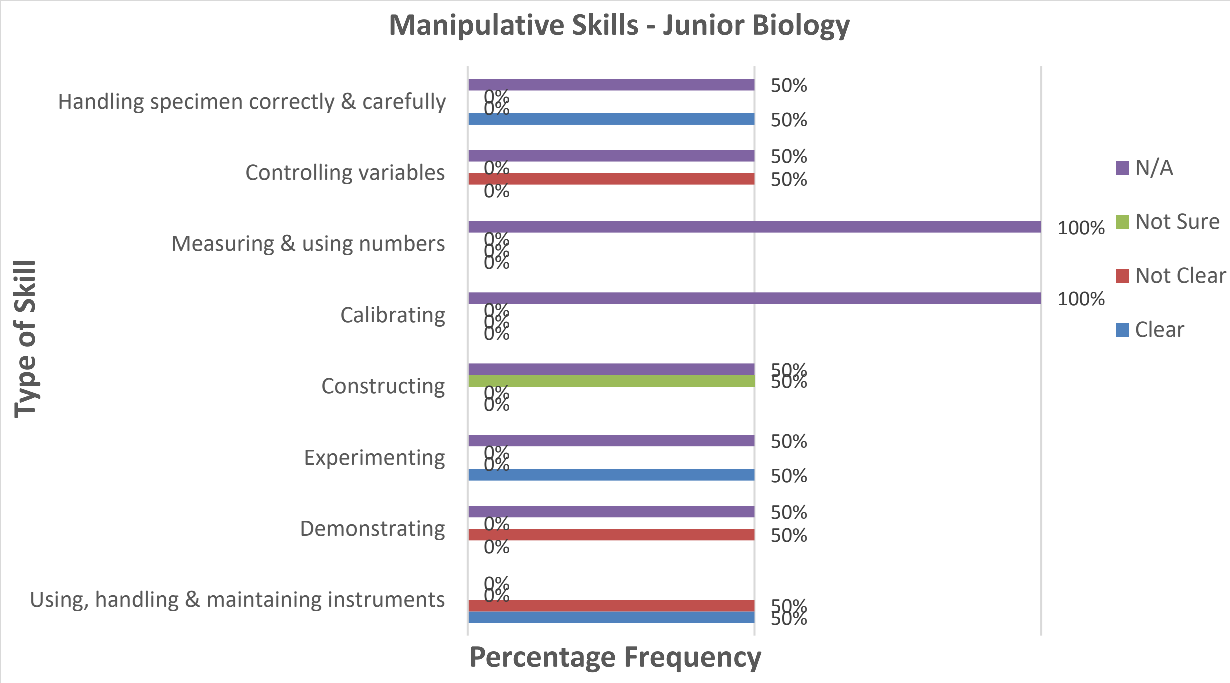


Figure 193: Manipulative Skills - Junior Biology

Figure 195 shows results of Manipulative Skills for lessons observed at Senior level. The findings indicated that of the 6 types of skills exhibited, 3 skills (Using, handling & maintaining instrument, Constructing and Controlling variables) were observed in 33% and the other 3 skills (Demonstrating, Experimenting and Handling specimen correctly & carefully) in 67% of the lessons respectively. The remaining 2 skills (Calibrating and Measuring & using numbers) were either not clear or not applicable.

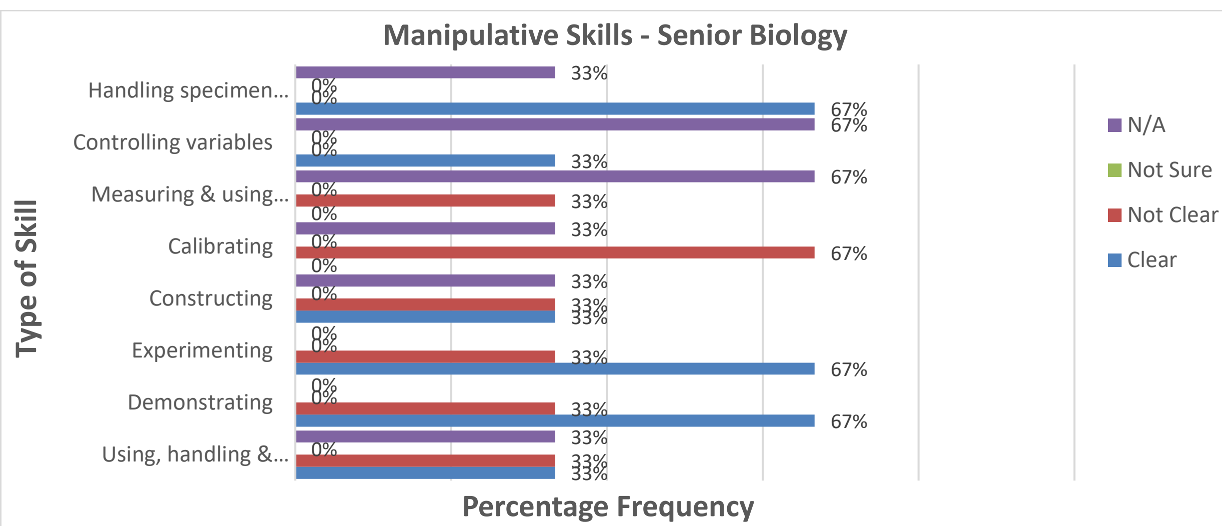


Figure 194: Manipulative Skills - Senior Biology

The results in Biology on Manipulative Skills for both Senior and Junior levels indicated that most lessons in Biology did not involve the activities that would bring out Manipulative Skills. The reason for such results might be that the lesson activities were designed with less emphasis on dexterity to allow learners handle materials and explore them in order to understand the underlying concepts. In STEM Education, for creativity to become operational, there is need to strengthen manipulative skills. Manipulative skills help learners to develop even more ideas about what has been created, such as on value addition, modification and product improvement. Therefore, learners ought to develop these skills during the learning process. The results shown above might imply that learners may not develop the agility needed for deeper appreciation of Biological diversity. In order to help teachers, develop shrewdness in the design of lesson activities that would engage learners more effectively there is need to continuously train them in constructivist approaches.

e) Communicative skills

Figure 196 indicates results on Communicative Skills in Biology at Junior level. The findings showed that out of 9 Communicative Skills 5 were exhibited in all the lessons observed, 3 skills (Reporting, Critiquing and Teaching) in 50% of the lessons while Graphing as a skill was not applicable in all the lessons observed.

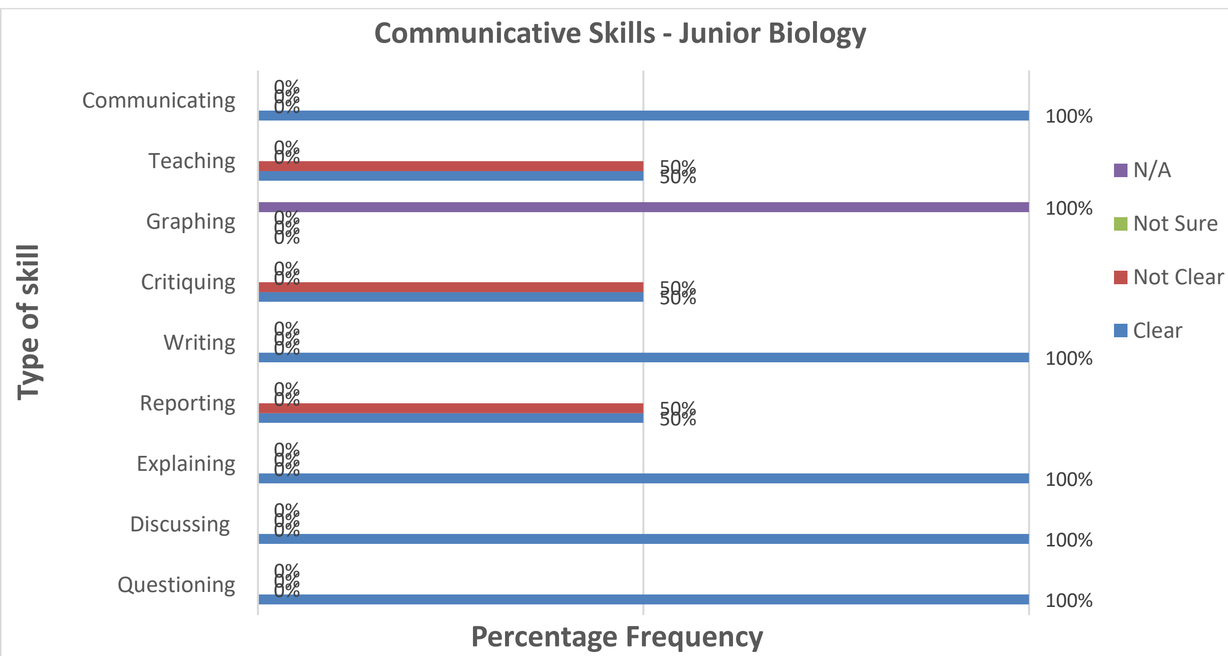


Figure 195: Communicative Skills - Junior Biology

At Senior level all Communicative Skills, with the exception of Critiquing and Graphing, were clearly observed in the Biology lessons. In 67% of the lessons Graphing skill was not applicable while Critiquing was not clear in 33% of the observed lessons as shown in Figure 197.

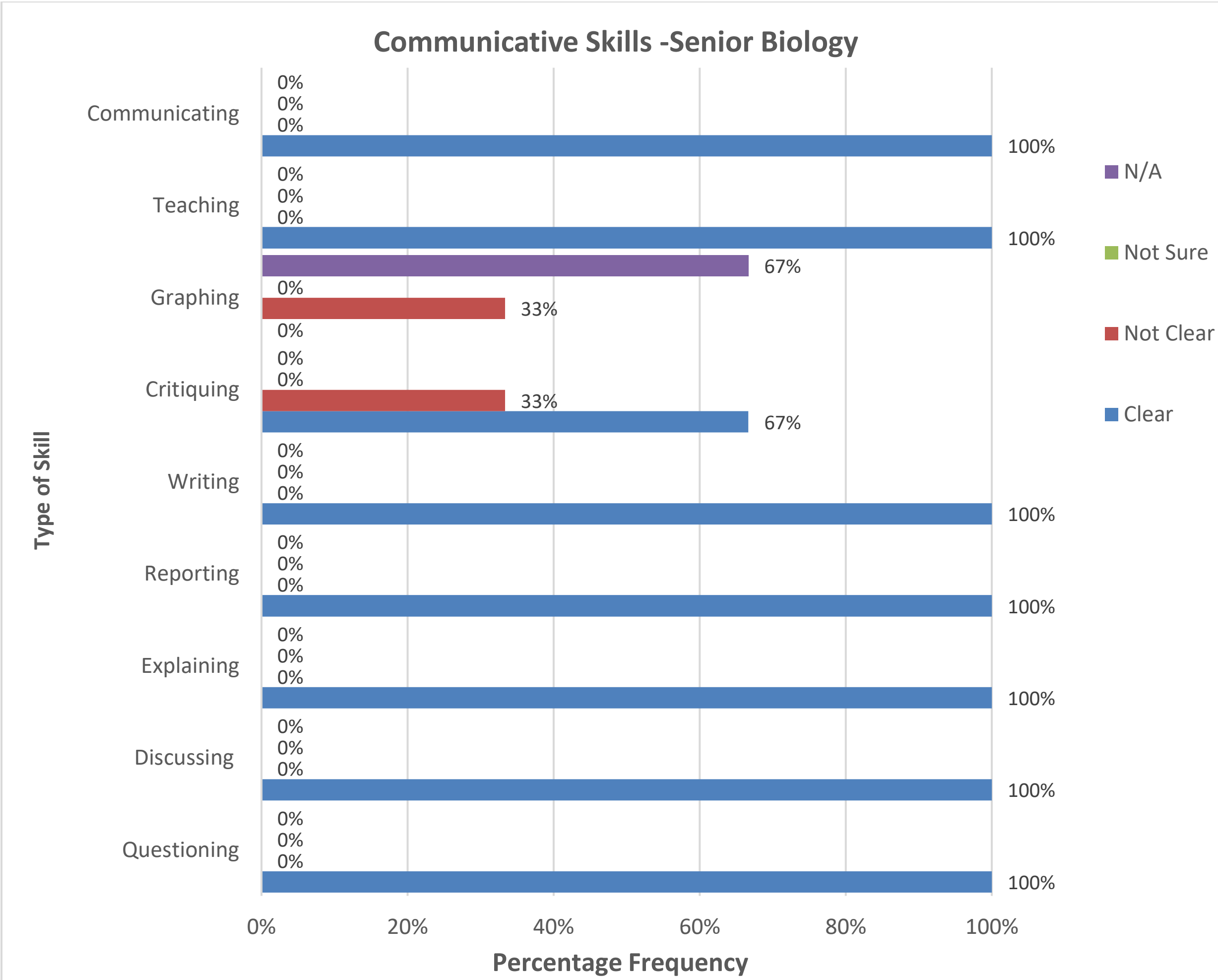


Figure 196: Communicative Skills -Senior Biology

The results from Figures 196 and 197 indicate that, there was impressive achievement in Communicative Skills for both Senior and Junior levels. This could have been that the learners were accorded the opportunities to teach, question, discuss and explain amongst themselves during teaching and learning process. The implication of this is that the skills that the learners exhibited could be used as a springboard for the development of other skills where results were not as expected. To this effect, teachers should be engaged more in tailored training and SBCPD activities in order to extend the techniques used in Communicative Skills to the other skills.

4.1.15.3.Chemistry

a) Acquisitive Skills – Chemistry

Figure 198 shows results on Acquisitive Skills as observed in Chemistry lessons at Junior level. It was observed that all the Acquisitive Skills, except for researching, were exhibited in the learners in all Chemistry lessons.

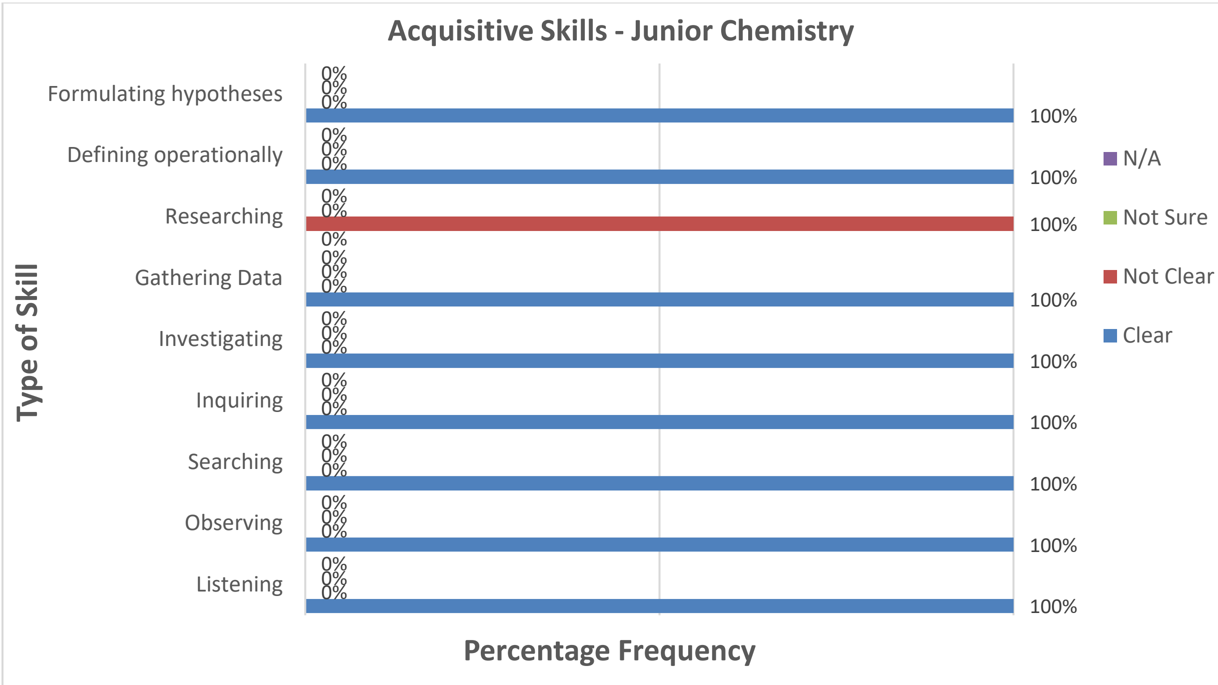


Figure 197: Acquisitive Skills - Junior Chemistry

At Senior level, 2 types of the skills (listening and observing) were clearly observed in all the lessons while the other skills were present in 75%, 50% or 25% lesson observed as shown in Figure 199.

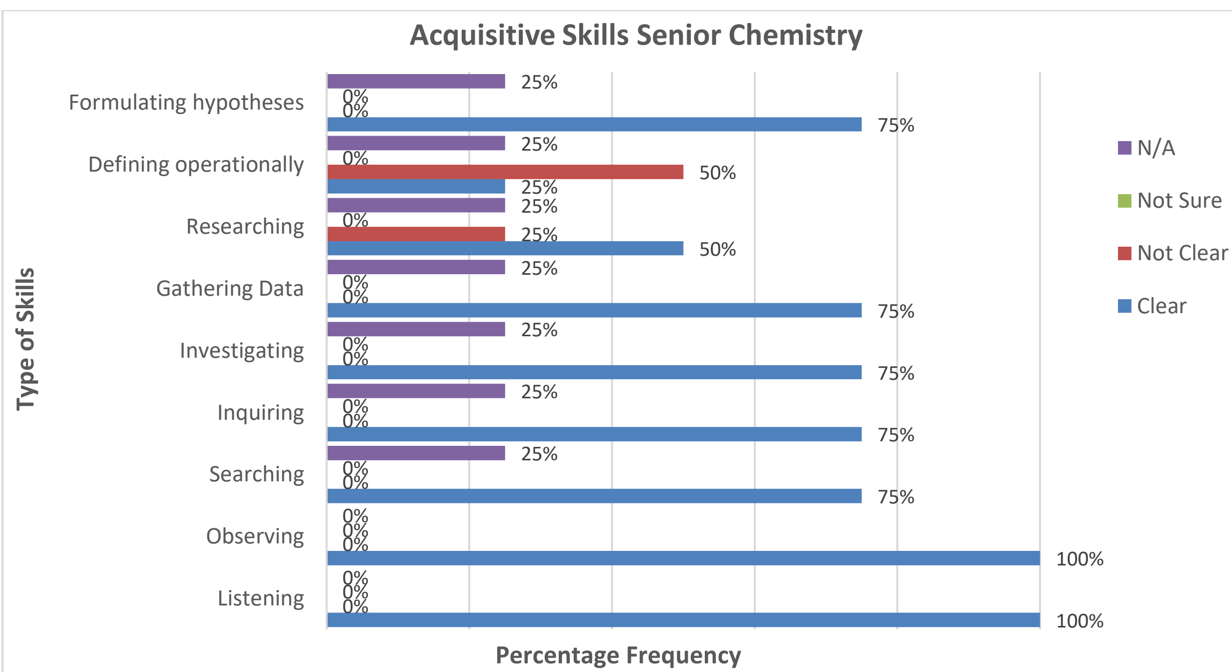


Figure 198: Acquisitive Skills Senior Chemistry

The remarkable and above-average results at Junior and Senior levels respectively, are an indication that the planned and delivered lesson activities were able to foster the needed acquisitive skills. However, the research skill that was not adequately explored raises concern as it entails that learners where not provided with opportunities to systematically investigate concepts in order to establish facts as they gathered information. This might be as a result of inadequate understanding of curriculum intensions by teachers and consequently, the prepared and delivered activities that were unable to bring forth research skills in learners. A few variations between the Junior and Senior level results could have been due to the fact that, a wide range of materials might not have been consulted during preparation for lessons. This could lead learners not to be creative, innovative, critical thinkers and problem solvers. There is need for teachers, therefore, to consult each other and practice team planning and teaching.

b) Organizational Skills – Chemistry

Organizational skills comprise 11 types of skills as shown in Figure 200. Of these 8 skills were clearly observed in all the Chemistry lessons at Junior level. The other 3 skills (contrasting, evaluating and interpreting data) were not exhibited in all the lessons.

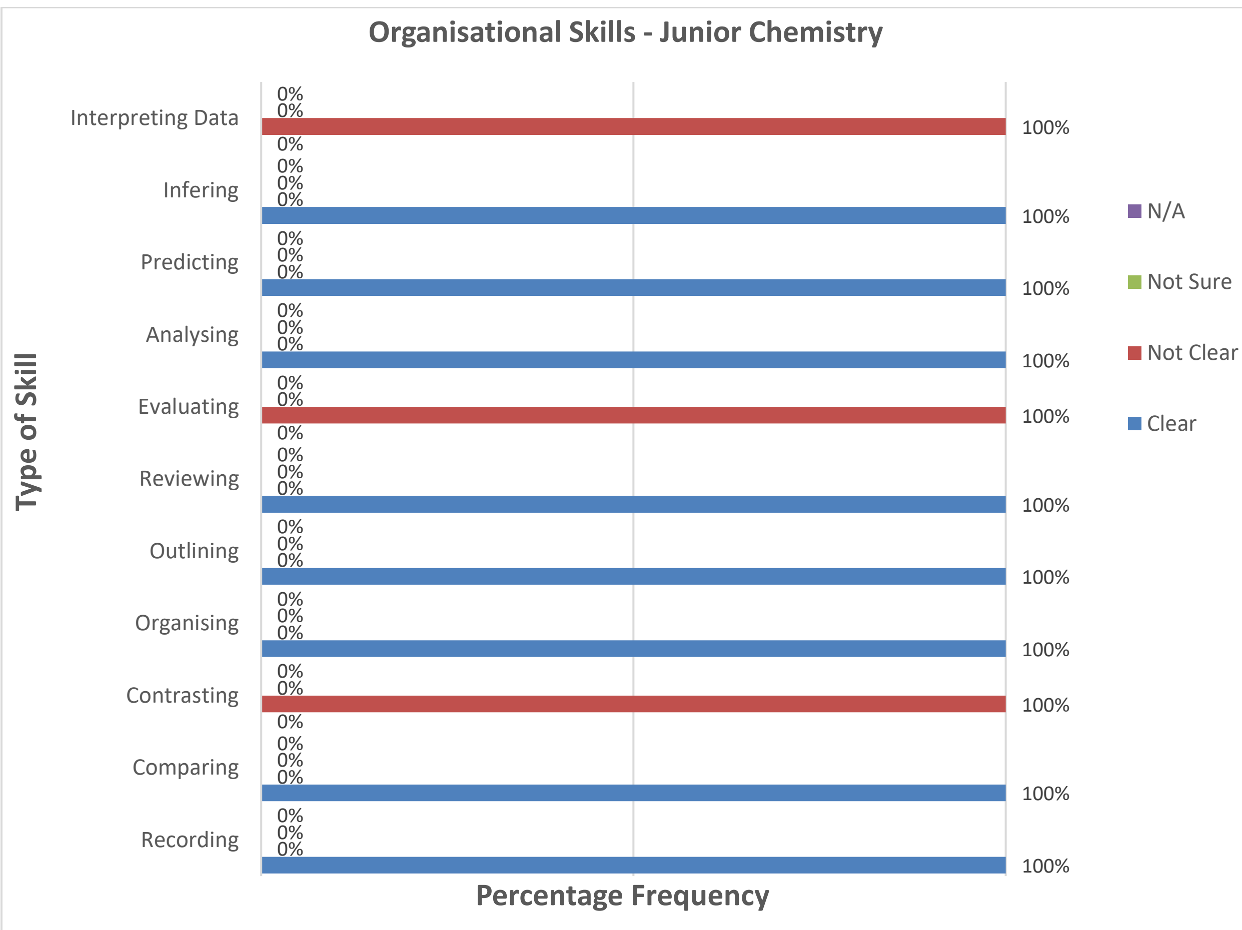


Figure 199: Organisational Skills - Junior Chemistry

At Senior level all the lessons clearly scored Organizational Skills above average except for evaluating which was at 25%. It was however observed that contrasting, inferring, interpreting data and evaluating were not clearly exhibited as shown in Figure 201.

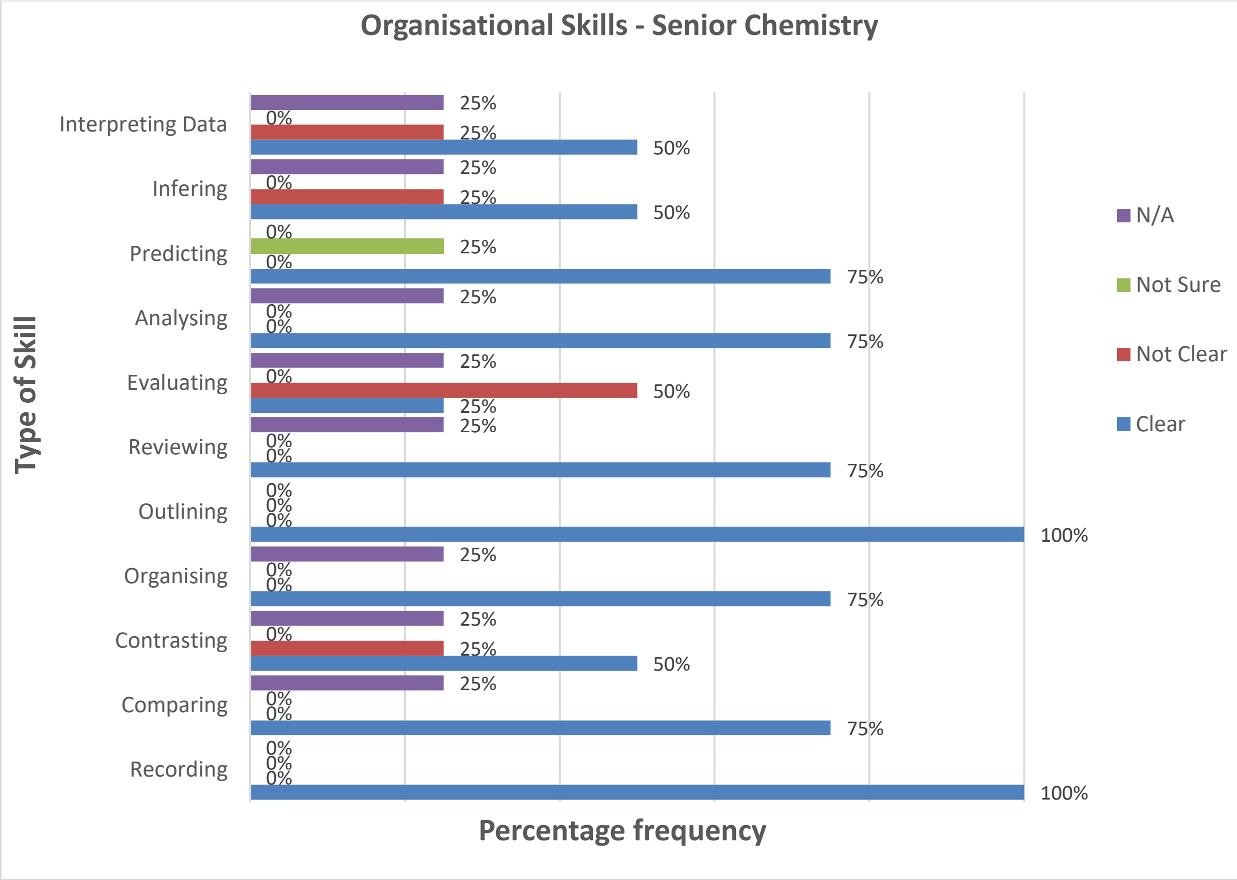


Figure 200: Organisational Skills - Senior Chemistry

As regards to Chemistry organizational skills, the learners both at Senior and Junior levels considerably achieved skills in conformity with the curriculum intentions. This could have been due to the fact that teachers interacted effectively with the curriculum and hence were able to interpret its dictates correctly as they planned and delivered the lessons. This facilitated the acquisition of the skills needed for organising data for easy interpretation and inference. The implication of this is that the skills that the learners were expected to acquire and develop were all suitably planned for and so the lessons were able to yield the desired outcomes. For the skills such as contrasting, evaluating and interpreting data, which were not clearly observed at both Senior and Junior levels there is need for teachers to engage in CPD activities to share knowledge and deepen their understanding of curriculum intentions and appropriate choice of strategies aimed at improving skill acquisition.

c) Creative Skills - Chemistry

Figure 202 shows results on Creative Skills for Chemistry at Junior level. The findings revealed that all lessons had the creative skills absent in the lessons observed.

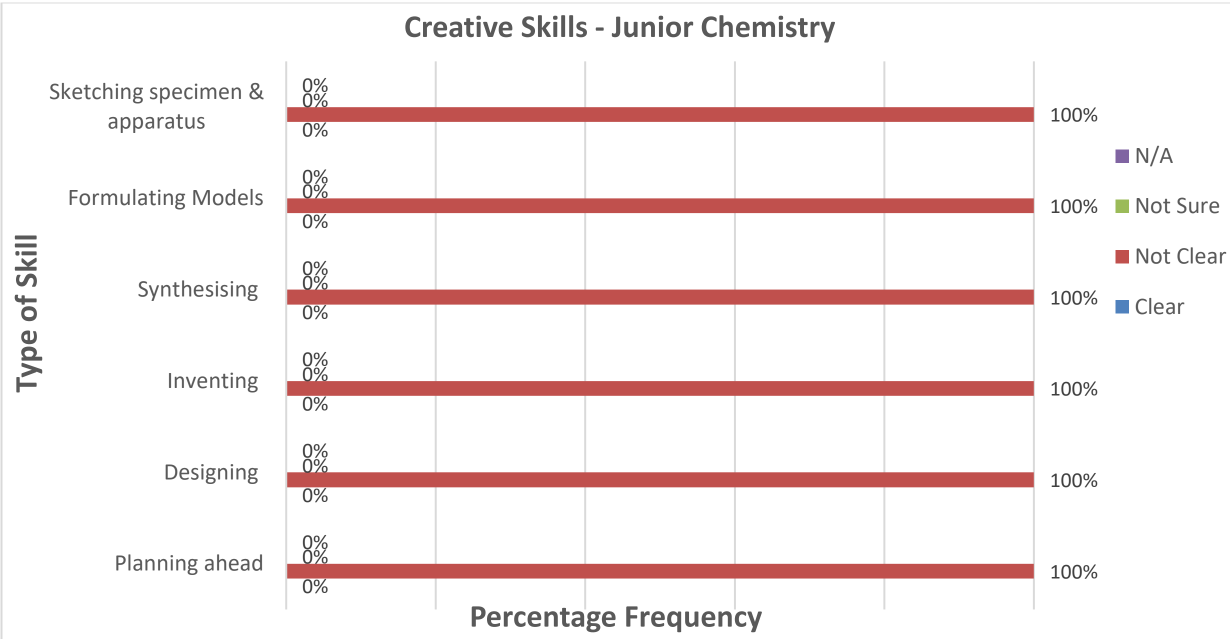


Figure 201: Creative Skills - Junior Chemistry

At Senior level, Figure 203 reveals that Designing and Synthesising skills were exhibited in 50% of the lessons, while the rest of the skills were manifested in only 25% of the lessons.

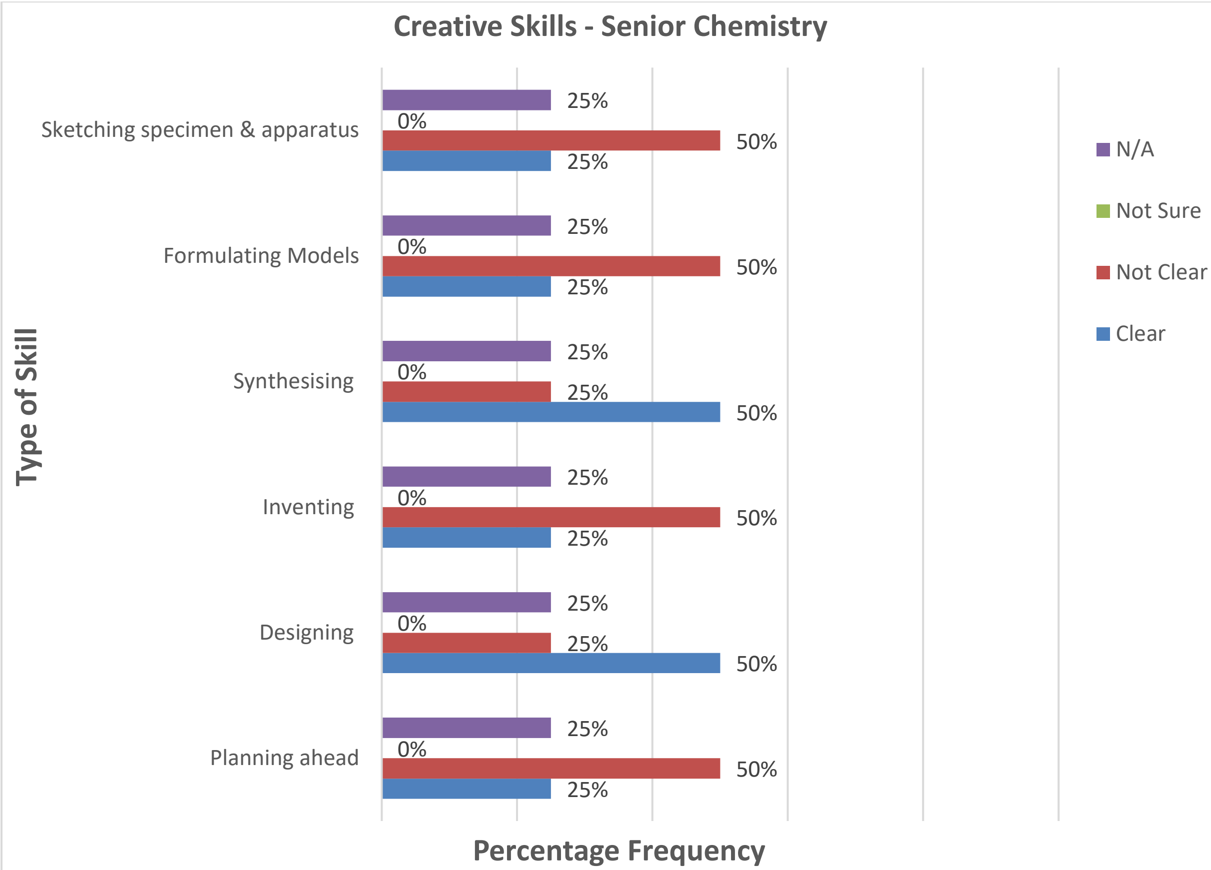


Figure 202: Creative Skills - Senior Chemistry

The findings in the Chemistry lessons as regards to creative skills showed that, there was low ability of lesson activities to foster creative skills in learners at both Senior and Junior levels. The learners at both levels showed very limited acquisition of creative skills. The reason for this could have been that the curriculum knowledge amongst teachers was not adequately understood so as to prepare and deliver activities that would promote the acquisition creative skills needed in the 21st Century. The implication of this could be that the intentions of the STEM Education Curriculum which aim at producing a creative thinker would not be achieved, hence, the need for teachers to continuously involve themselves in professional development programs.

d) Manipulative Skills – Chemistry

Figure 204 shows the types of Manipulative Skills observed in Chemistry at Junior level. The findings revealed that all the lessons had 5 skills clearly observed while constructing and measuring & using numbers were not clearly exhibited. The skill of calibrating was not displayed in all the lessons.

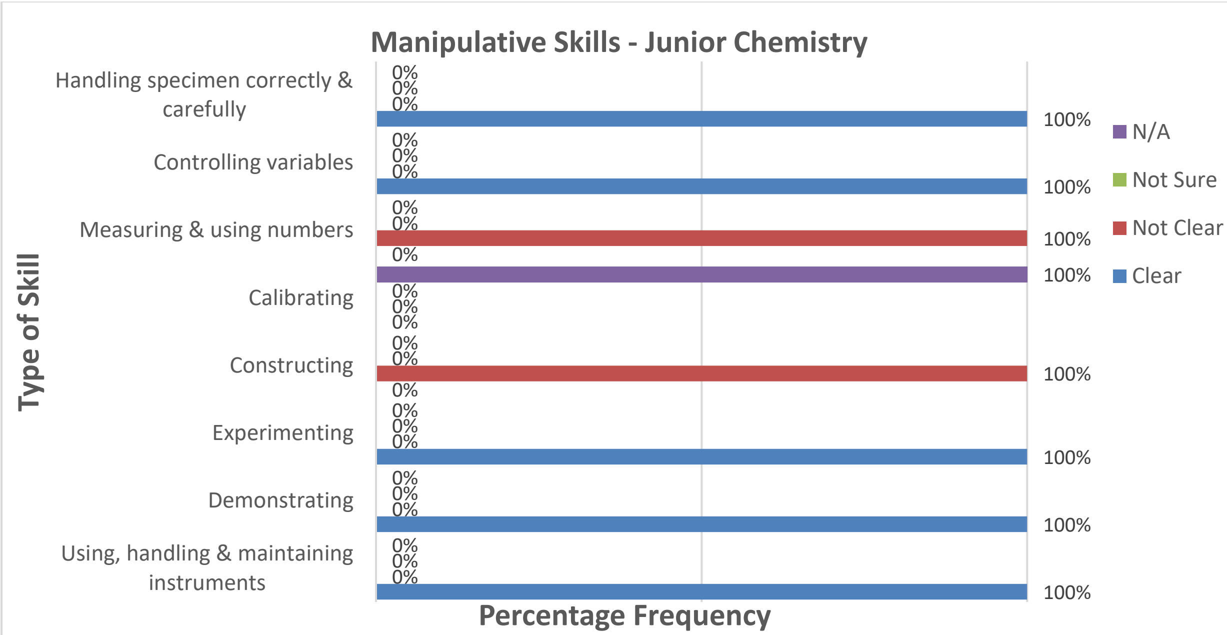


Figure 203: Manipulative Skills - Junior Chemistry

At Senior level there was above-average exhibition of 6 skills expect for Calibrating, and Measuring & using numbers. This is shown in Figure 205.

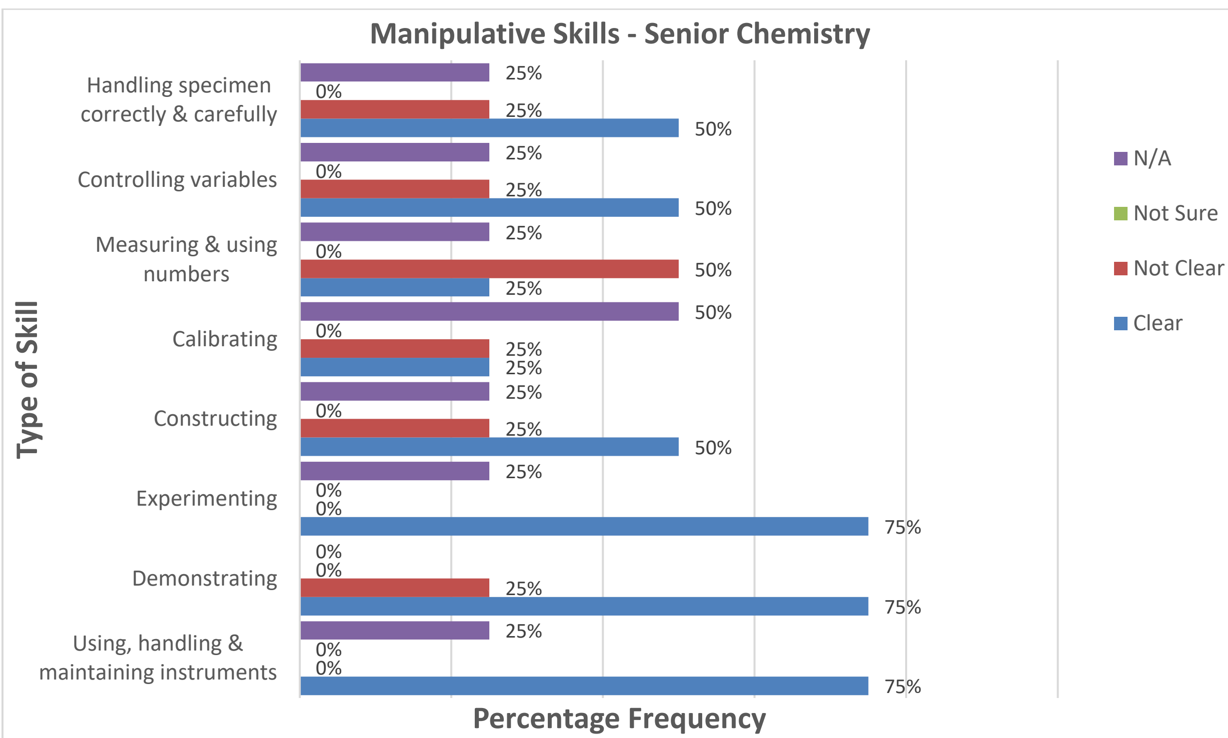


Figure 204: Manipulative Skills - Senior Chemistry

The Chemistry results as regards to Manipulative Skills were generally available at both levels expect for constructing, calibrating as well as measuring & using numbers which were completely absent at Junior level. The overall Manipulative Skills exhibited, could have been as a result of teachers having interacted effectively with the curriculum and hence were able to interpret its dictates correctly as they planned and delivered the lessons. However, the low exhibition of skills for constructing, calibrating as well as measuring & using numbers is a source of concern in STEM Education. This is so because learners will be deprived of the opportunity to use instruments and record readings accurately. It would also be difficult for learners to carry out accurate constructions without Manipulative Skills. This meant that the activities planned for fell short in soliciting for effective engagement and exploration amongst learners. The reason for this could have been that there was inadequate knowledge as to what the activities during the lessons should comprise. Teachers should prepare strategies and tasks that will promote the use of demonstrations and experiments and ensure that learners' participation is existent. The hands-on experiences will improve the chances of learners' understanding the lessons as they may enhance the cognitive level at which the learners' will be able to apply the knowledge and skills acquired. To this effect, the teachers should to continuously engage in professional development activities so as an in-depth understanding of curriculum aspects and ultimately impact positively on learners' achievement.

e) Communicative Skills - Chemistry

In the context of STEM Education, the Communicative Skills domain comprises 9 skills. Out of these 7 skills were clearly observed in all the lessons at Junior level as shown in Figure 206. However, the skill of explaining was absent in all the lessons observed while the graphing skill was not applicable in the lessons.

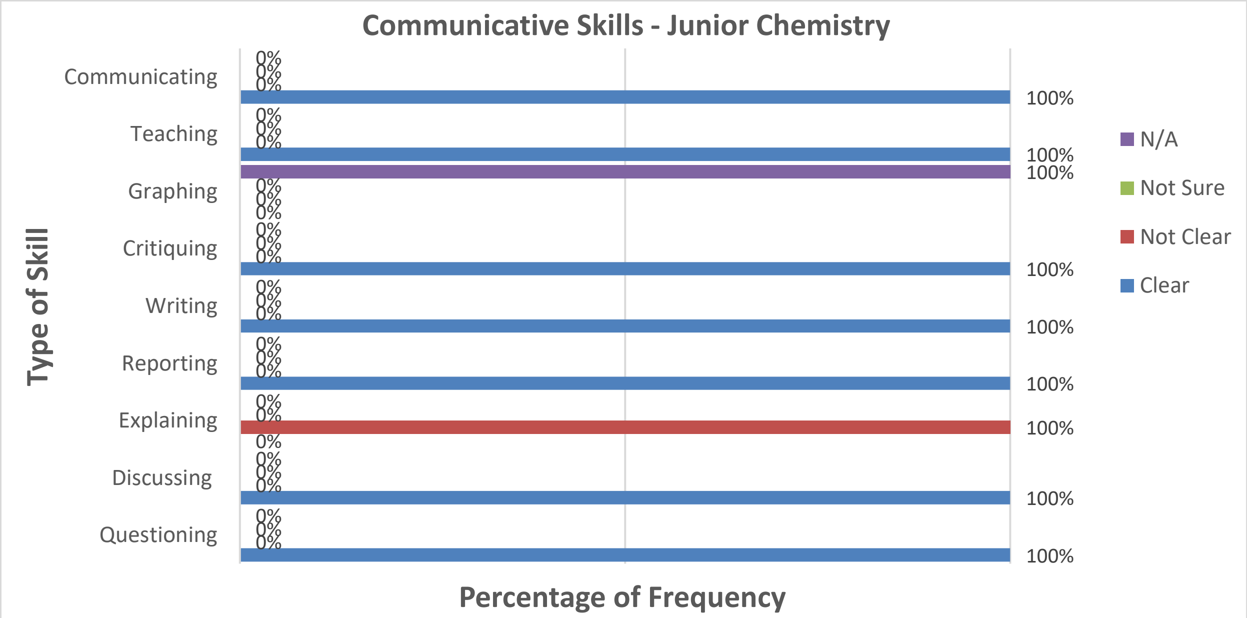


Figure 205: Communicative Skills - Junior Chemistry

At Senior level all the Communicative Skills were clearly observed except for the graphing skill which was not applicable in 75% of the lessons as shown in Figure 207.

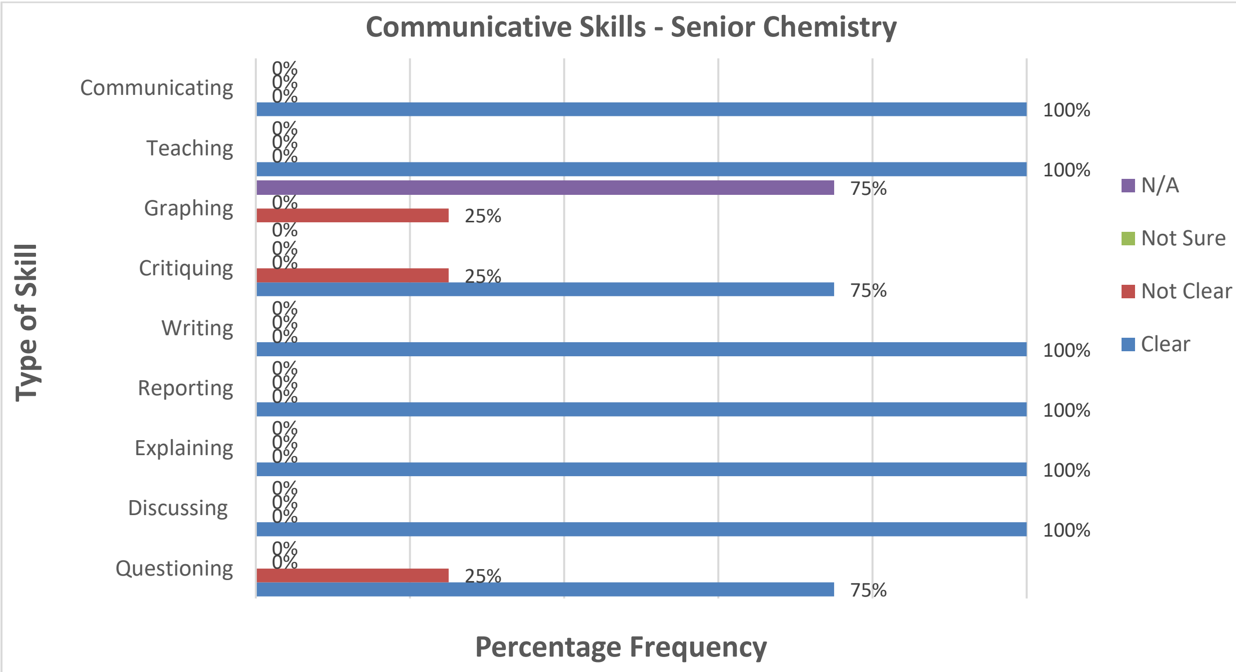


Figure 206: Communicative Skills - Senior Chemistry

The results indicate that, there was substantial achievement in Communicative Skills for both Senior and Junior levels. The reason for this could have been that the learners were given chance to express themselves freely through discussions, questioning, explaining and writing. Learners communicated with both their peers and teachers through presentations and further contribution from the entire class. This facilitated the acquisition of the skills needed for the learner to be creative, innovative, critical thinker and problem solver. The implication of this is that the skills that the learners were expected to acquire and develop were planned for and so the lessons produced the desired outcomes. However, there is need for teachers to consider the skills of explaining and graphing as they plan tasks and activities for their lessons in order to develop these skills in the learners. This can be achieved by teachers engaging in CPD activities so as to have an in-depth understanding of curriculum aspects and acquire PCK in order to develop Communicative Skills.

4.1.15.4. Computer Science

a) Acquisitive Skills – Computer Science

Figure 208 shows results on Acquisitive Skills in Computer Science at Junior level. The findings indicated that all the types of the Acquisitive skills were clearly observed in the lessons except for the skill of formulating hypotheses.

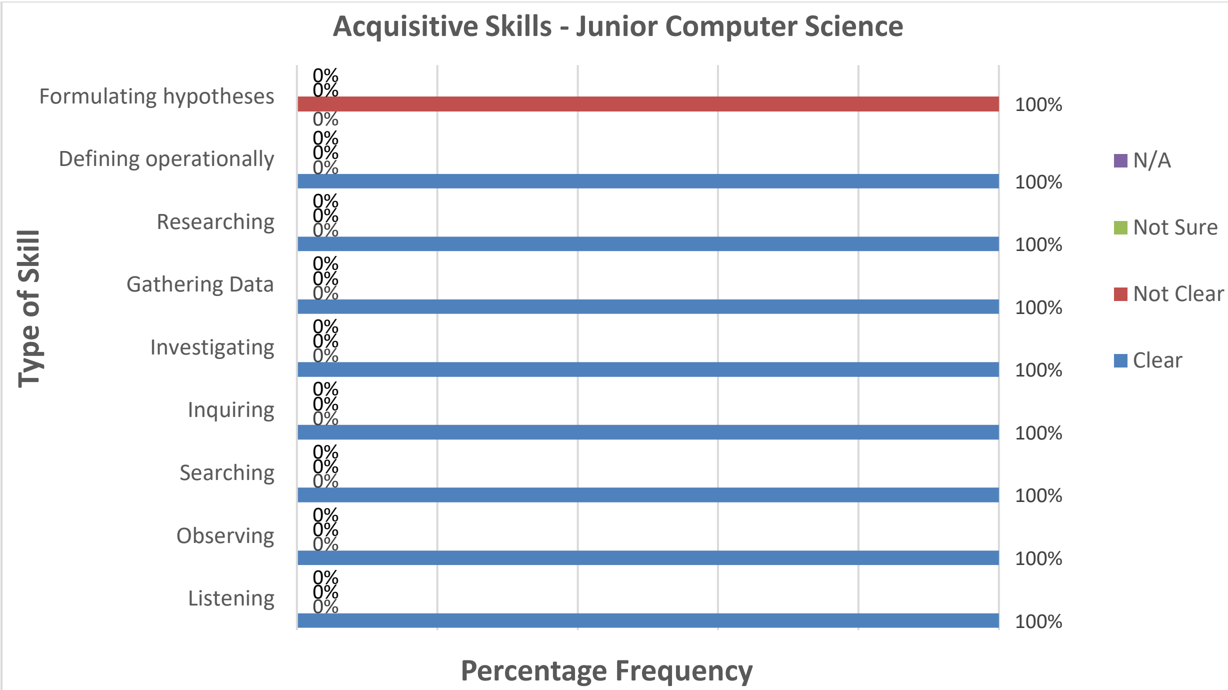


Figure 207: Acquisitive Skills - Junior Computer Science

Figure 209 indicates results on Acquisitive Skills in Computer Science at Senior level. The results revealed that all Acquisitive Skills were displayed in all the lessons at this level with 5 types of skills being displayed in more than 50% of the lessons observed. On the contrary, some skills such as formulating hypotheses, defining operationally and gathering data were lowly exhibited.

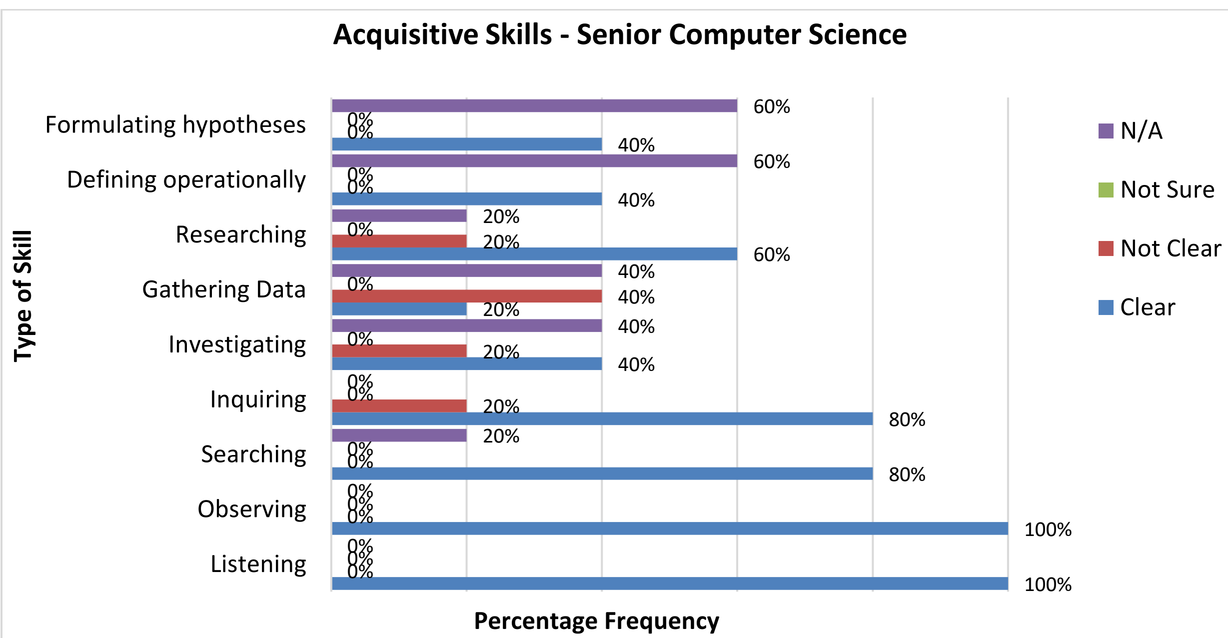


Figure 208: Acquisitive Skills - Senior Computer Science

As shown in the results for Senior Computer Science in the category of Acquisitive Skills, there was an inability to gathering data skill. This could have been due to the kind of activities which learners were involved in which could not provoke them enough to look for more information about the tasks. The cause of such could have been the level at which they were making it easier for them to gather fewer points and hoping to talk more from their experiences. However, it may also be argued that the lower ability shown in investigating and researching might have also contributed to the cause of the reduced ability in gathering data. The limited resources to refer to during their learning processes might have exacerbated the situation.

b) Organisational Skills – Computer Science

Figure 210 shows results on Organisational Skills in Computers Science at Junior level. The results revealed that all the skills except for predicting and interpreting data were above 50% in the lessons observed.

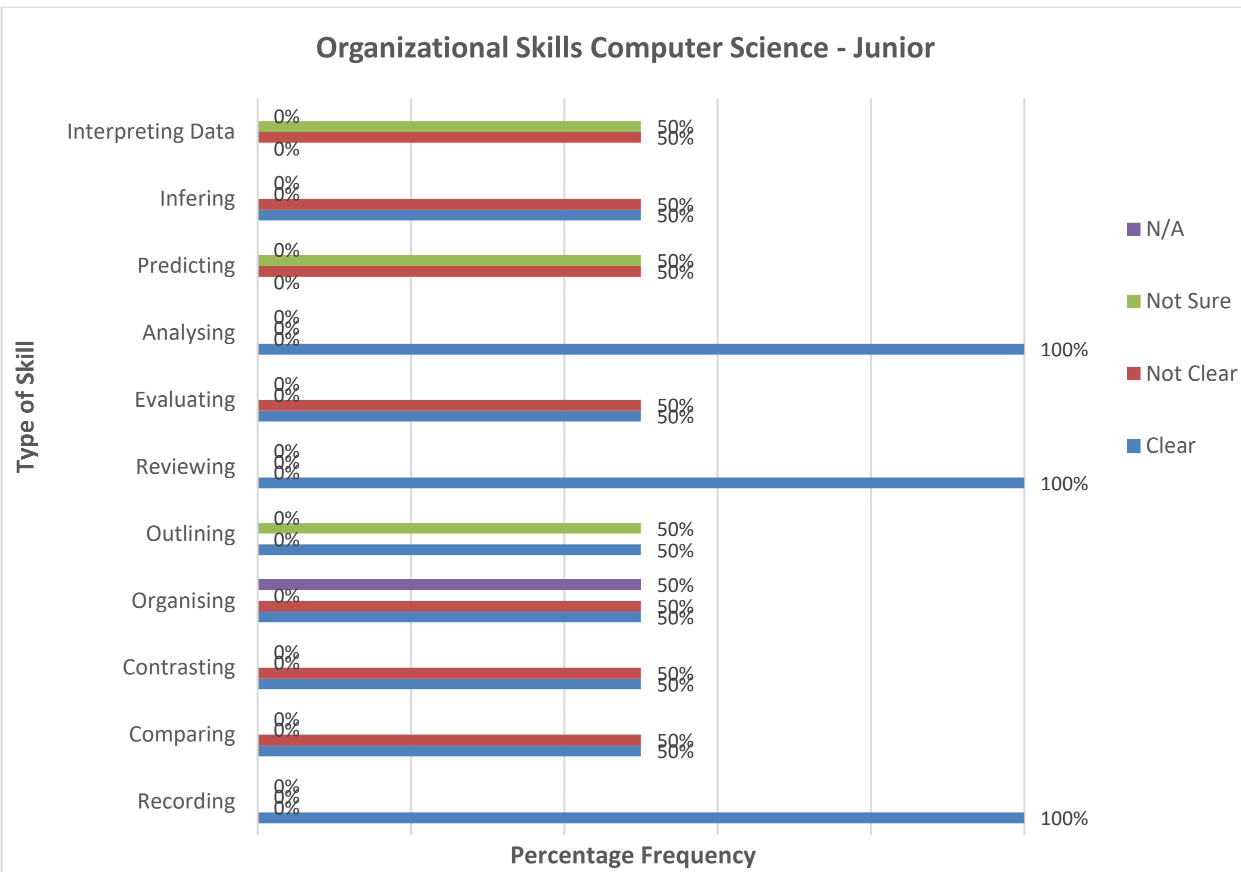


Figure 209: Organisational Skills Computer Science – Junior level

Figure 211 shows results on Organisational Skills in Computers Science at Senior level. The results indicated that all the skills were exhibited in more than 40% of the lessons observed.

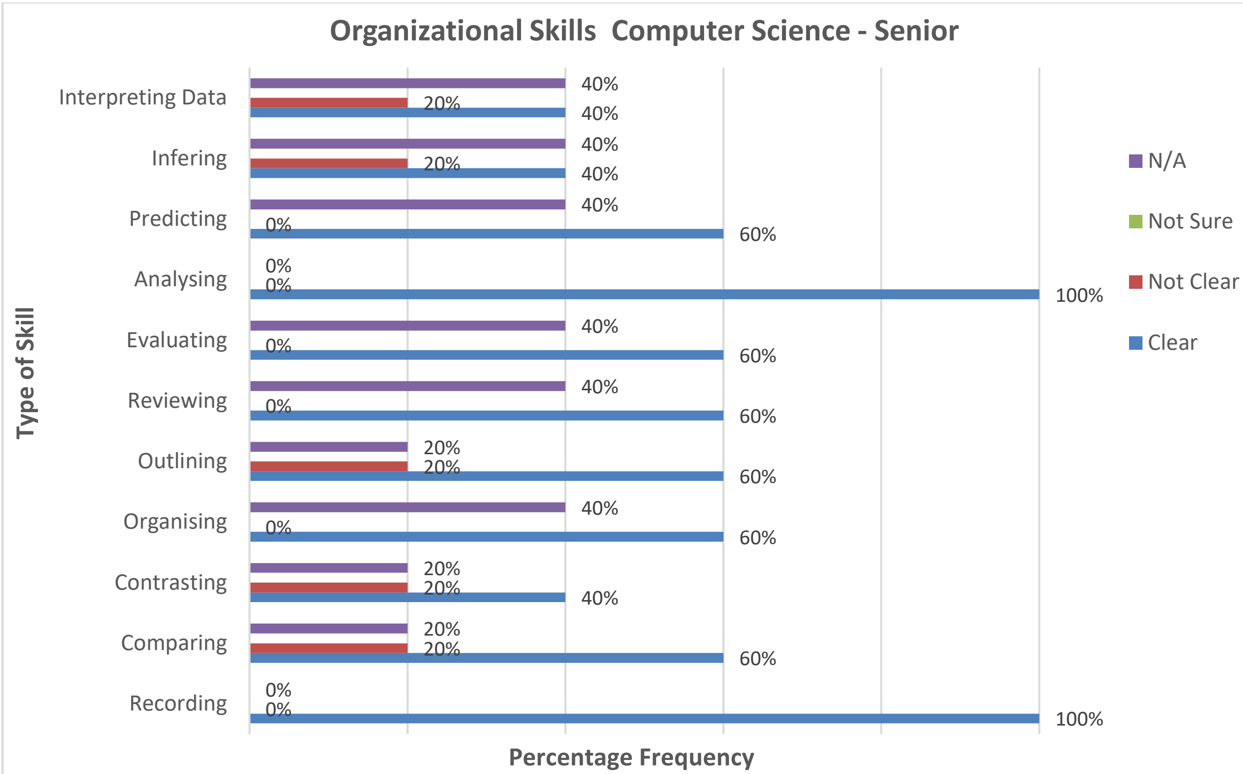
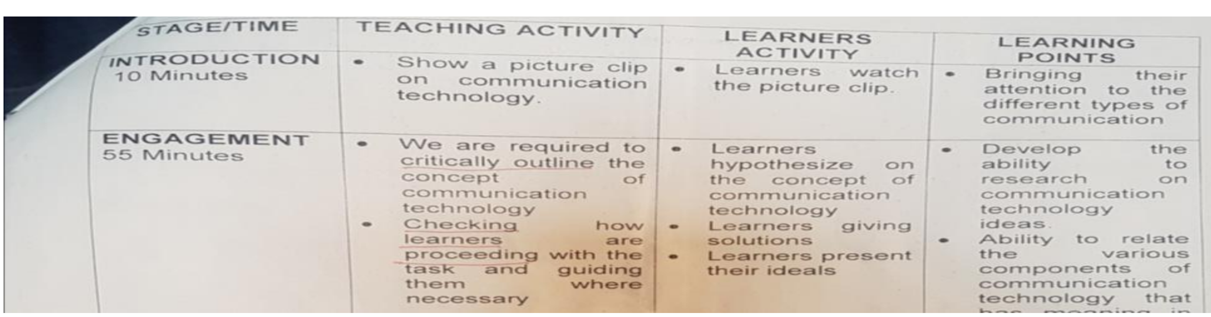


Figure 210: Organisational Skills Computer Science – Senior level

From the results it can be seen that the Organisational Skills were not well handled. This could be due to the way the tasks and activities were organised during the lessons. For instance, in the lesson at Junior level whose lesson outcomes were "*capable of identifying various components of communication technology such as people, data, hardware, software, information, protocols etc."* and *"capable of identifying barriers to effective communication and how to enhance communication technology by use of protocols",* the learners' activities as indicated on the lesson plan were: *"learners hypothesise on the concept of communication technology, learners giving solutions, and learners present their ideals".* These learner activities cannot produce Organisational Skills because there are no tasks that will bring out the expected skills as shown in Figure 212.



STAGE/TIME	TEACHING ACTIVITY	LEARNERS ACTIVITY	LEARNING POINTS
INTRODUCTION 10 Minutes	• Show a picture clip on communication technology.	• Learners watch the picture clip.	• Bringing their attention to the different types of communication
ENGAGEMENT 55 Minutes	• We are required to critically outline the concept of communication technology • Checking how learners are proceeding with the task and guiding them where necessary	• Learners hypothesize on the concept of communication technology • Learners giving solutions • Learners present their ideals	• Develop the ability to research on communication technology ideas. • Ability to relate the various components of communication technology that

Figure 211: Sample lesson Plan on Learner Activities

The implication of this could be that the teachers did not have PCK to interpret the Curriculum intentions and formulate appropriate tasks and activities on the concepts in order to develop Organisational Skills in the learners. It is therefore, recommended that teachers ought to engage in CPD activities so as to empower themselves with the knowledge and strategies required for effective teaching.

c) Creative Skills – Computer Science

Figure 213 shows results on Creative Skills in Computers Science at Junior level. The results disclosed that only the skills of Planning ahead and Synthesising were present in 33% of the lessons observed. The rest of the Creative Skills were not exhibited.

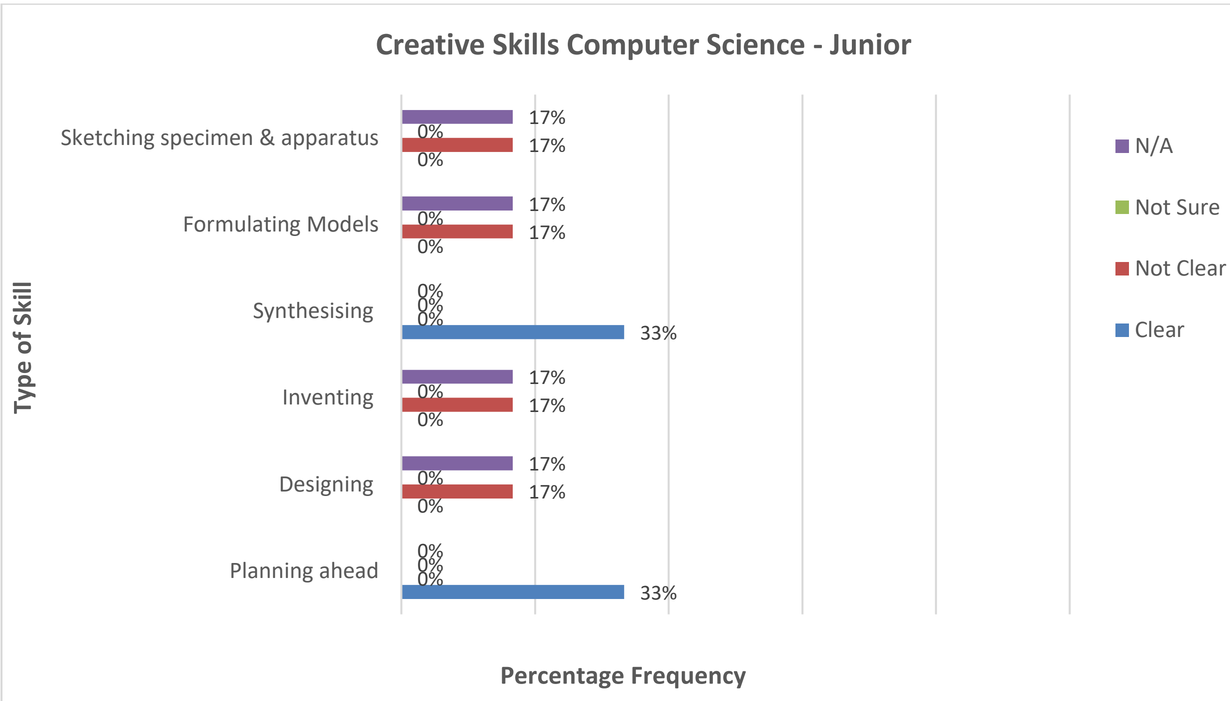


Figure 212: Creative Skills in Computers Science at Junior level

Figure 214 shows results on Creative Skills in Computers Science at Senior level. The results indicated that the skills of Designing and Formulating models were present in 40% of the lessons while the rest of the skills were only present in 20% of the lessons observed.

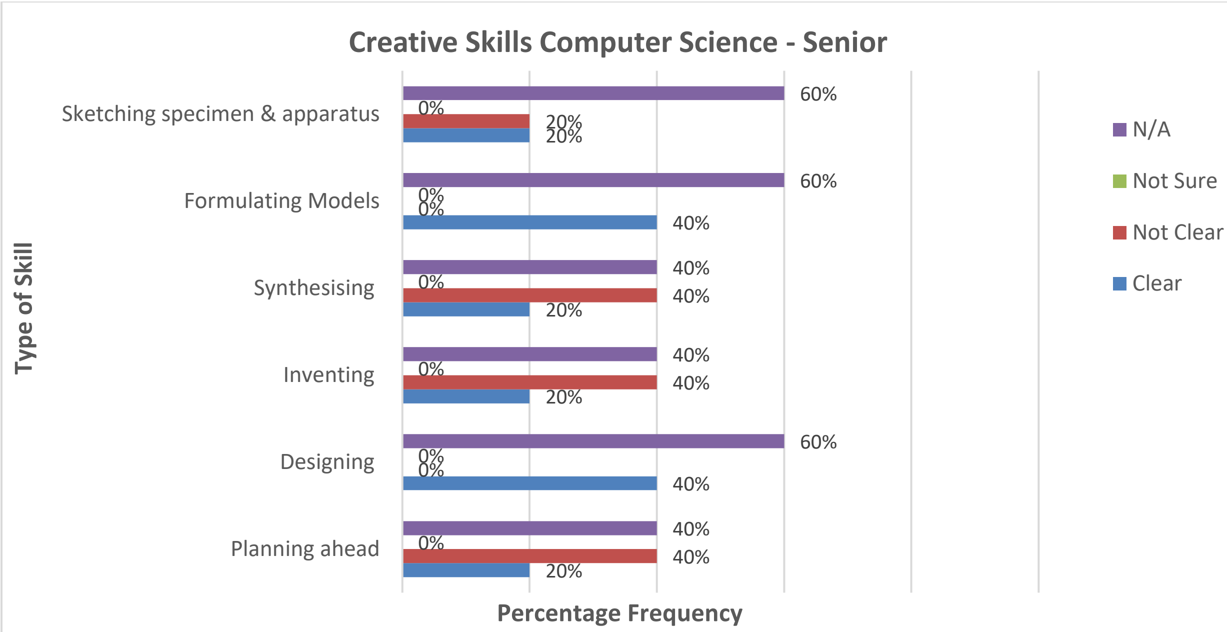


Figure 213: Creative Skills in Computers Science at Senior level

Creative Skills entail that learners develop the ability to recognize and think in an inventive approach about physical events in order to generate new solutions and come up with something to address the present and future challenges. With the above revelations it was clear that these skills were not taken care of in the lessons. This could emanate from the way the learners' tasks and activities were set as shown in Figure 214. Teachers, therefore, need to intensively study the teaching and learning materials in order to formulate appropriate tasks for the learners to develop creative skills. This can be attained through SBCPDs and other capacity building activities.

d) Manipulative Skills – Computer Science

Figure 215 indicates results on Manipulative Skills in Computer Science at Junior level. The results revealed that only the skills of using, handling & maintaining instruments and demonstrating were clearly displayed in 50% of the lessons observed at this level. The other skills were not clearly displayed as indicated in the figure.

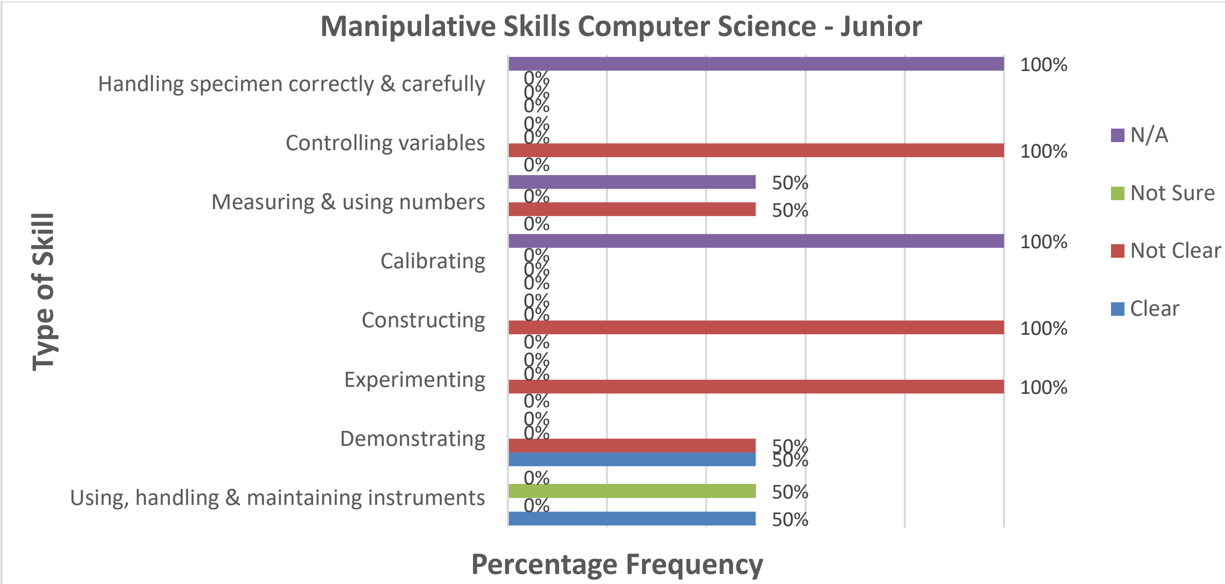


Figure 214: Manipulative Skills Computer Science - Junior

At Senior level the skills of using, handling & maintaining instruments and demonstrating were observed in 40% of the lessons while Experimenting, Constructing, Controlling variables and Handling specimen correctly were exhibited in 20% of the lessons observed. The remaining two; calibrating and measuring & using numbers were not either not clearly observed or not applicable as shown in Figure 216.

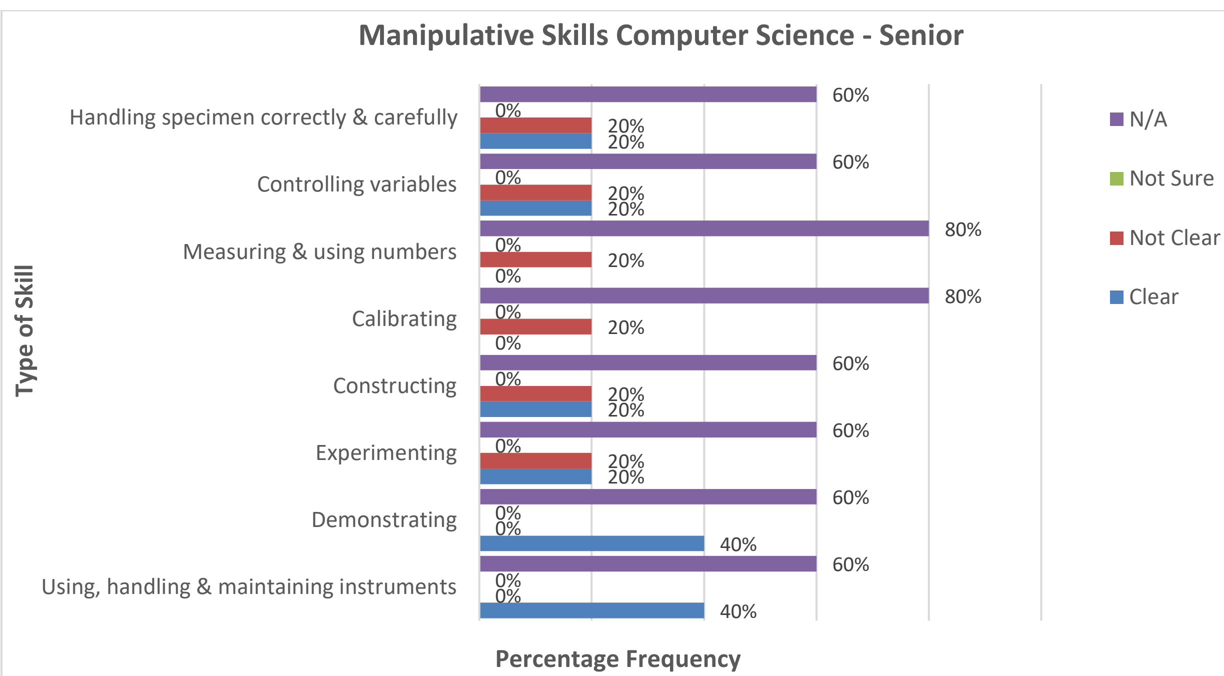


Figure 215: Manipulative Skills Computer Science - Senior

The results reveal that there were no activities in the lessons which would enhance the development of manipulative skills in learners especially in the Junior lessons. Again Figure 199, as a case in point, reveals that the learners' tasks did not contain any manipulative activities. The other reason might have to do with the way computers are treated where learners get the barest minimum of meaningful interaction apart from basic typing as they get threatened with consequences of damaging the devices. This limits the level of manipulation of these computers by learners during their processes thereby failing to manipulate them as expected. The implication would be that if left unchecked the trend might spiral to extents of learners not seeing the real value of the Computer Science subject leading to failure to attain the aspirations of the Curriculum. It could also imply that teachers did not understand the intentions of the STEM Education Curriculum especially on issues to do with the development of Scientific Skills. Therefore, there is need for teachers to spend time and understand the dictates of the Curriculum and research on best practices. This can also be achieved through Lesson Study during CPD meetings.

e) Communicative Skills – Computer Science

The results in Figure 217 shows Communicative Skills for Computer Science lessons observed at Junior level. The findings indicated that all the Communicative Skills were remarkably exhibited in all the lessons observed except for graphing skill.

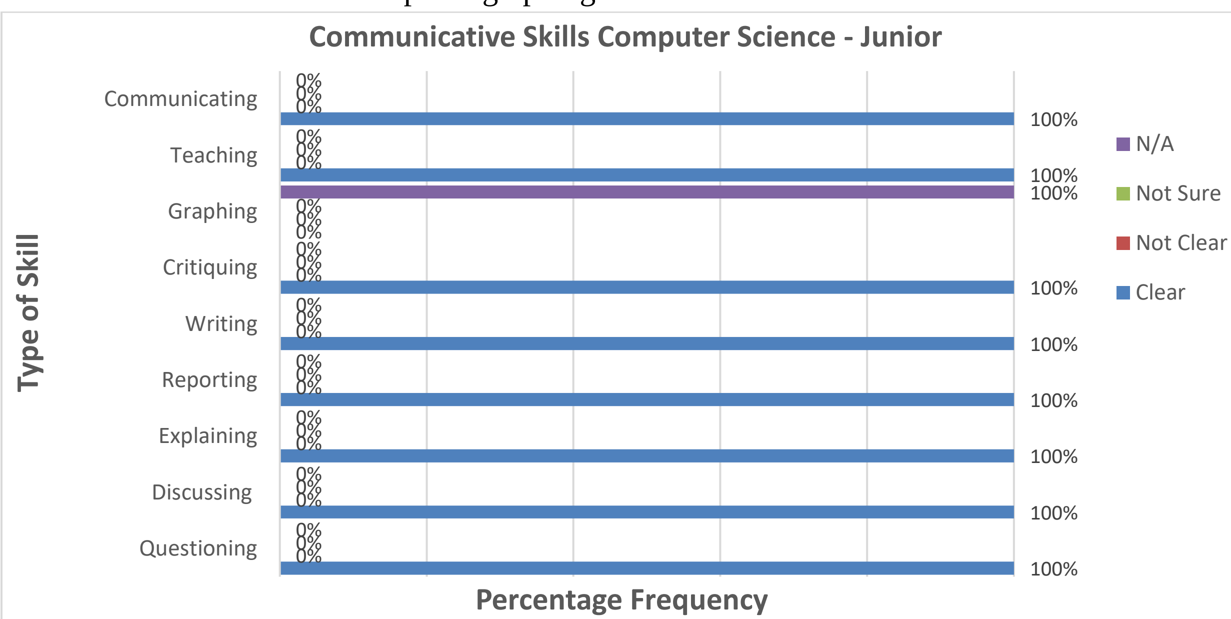


Figure 216: Communicative Skills Computer Science - Junior

Figure 218 indicates results in Communicative Skills for Computer Science at Senior level. The results revealed that all Communicative Skills were displayed in all the lessons observed at this level ranging from 20% to 100%.

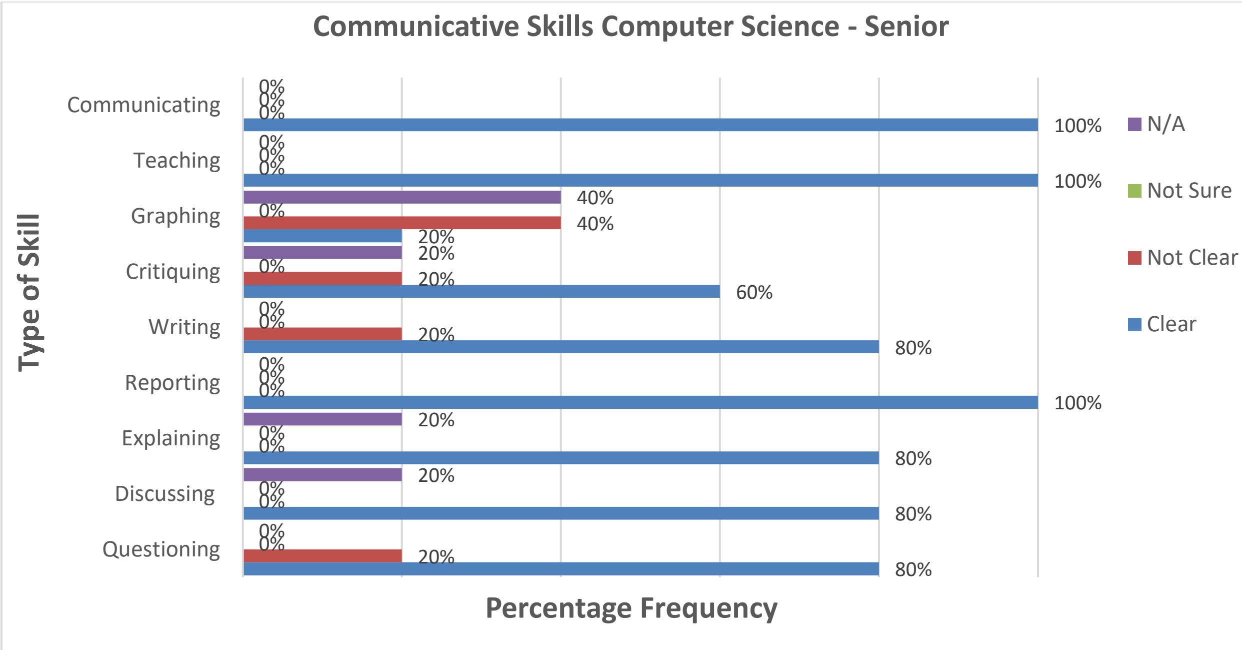


Figure 217: Communicative Skills Computer Science – Senior

The results indicated that there was effective Communicative Skills display in all the lessons at both Senior and Junior levels. This could be due to the fact learners were given the opportunity to communicate the findings as they presented their work. However, the skills of graphing at both levels and critiquing at Senior level were not adequately exhibited in the lessons observed. The reason could be that the tasks did not require this skill to be exhibited in some particular lessons. The implication of this may be that if adequately encouraged to communicate learners could develop the other skills as communication sets the pace for the rest of the abilities to be harnessed.

4.1.15.5.Design and Technology

a) Acquisitive Skills – Design and Technology

Figure 219 shows the results on Acquisitive Skills for Design and Technology at Junior level. The results indicated that the listening skill was clearly observed in all the lessons, the observing skill in 83% of the lessons while inquiring skill was observed in 50% of the lessons. The rest of the Acquisitive Skills were either exhibited in few lessons or not exhibited at all. Further, it was observed that some skills were reported not be applicable in some lessons as indicated in the figure.

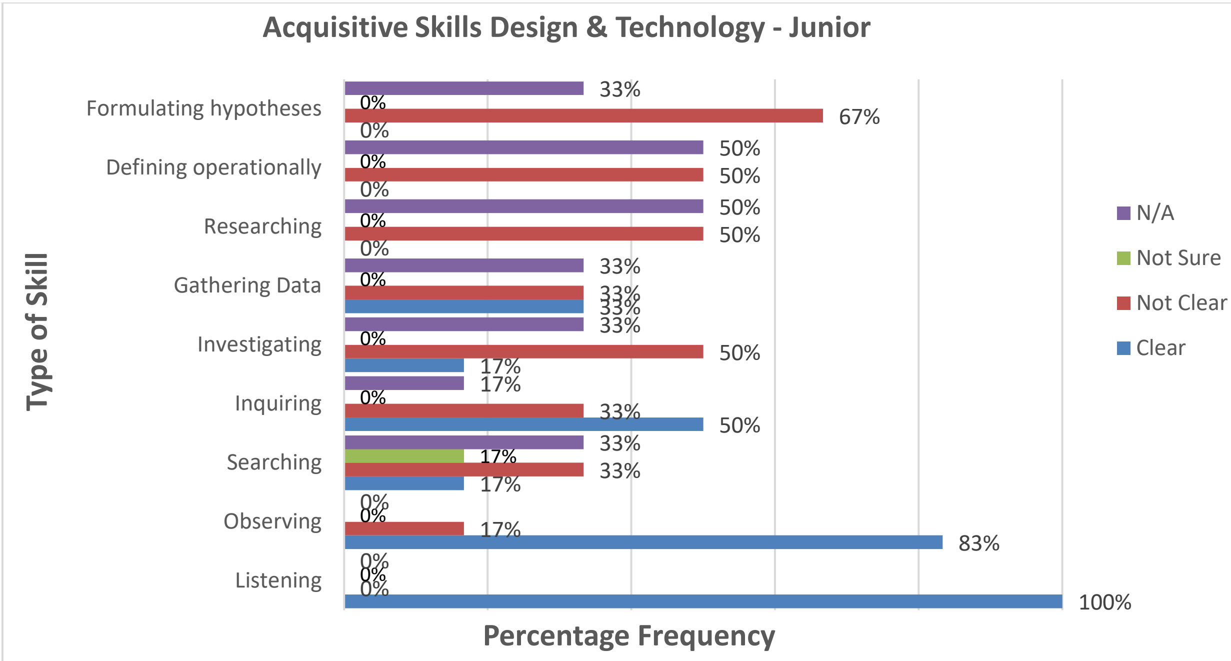


Figure 218: Acquisitive Skills Design & Technology – Junior

For the lessons at Senior level, it was observed that listening and inquiring were exhibited in all the lessons as shown in Figure 220. Observing as a skill was displayed in 67% of the lessons observed while searching, investigating, gathering data and researching were shown in 33% of the lessons. The rest of the Acquisitive Skills (defining operationally and formulating hypotheses) were predominantly reported not applicable.

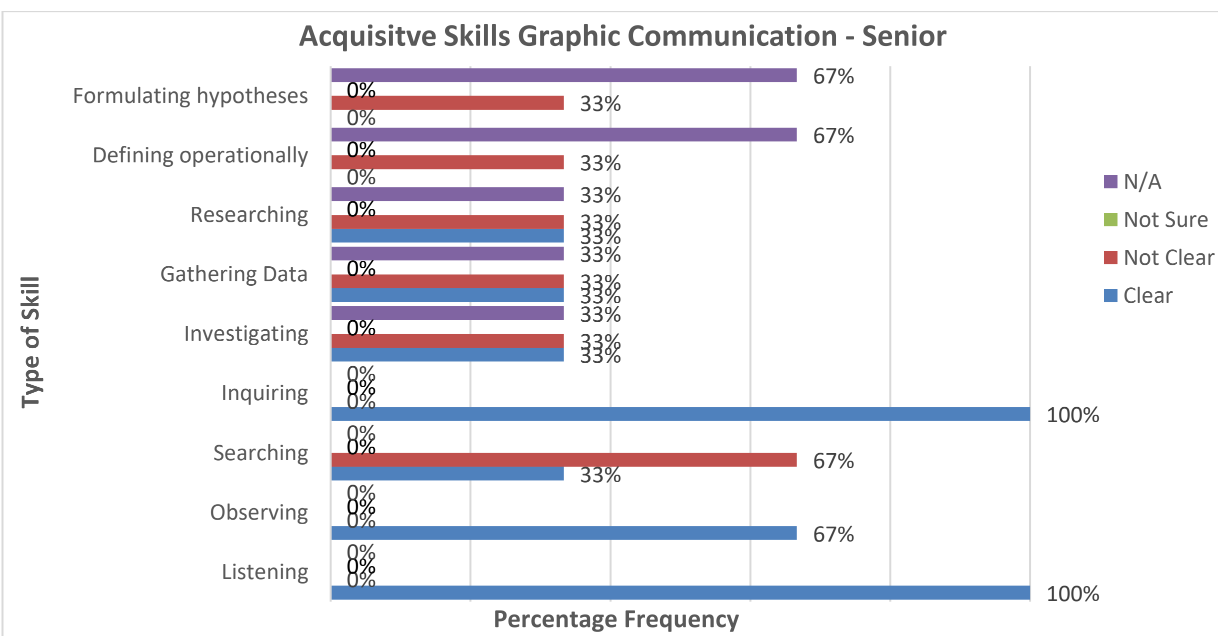


Figure 219: Acquisitive Skills Graphic Communication – Senior

In the case of Senior Design and Technology, Figure 221 shows the results in Acquisitive Skills for System Technology. The findings revealed that all the lessons observed exhibited 100% of all the types of skills.

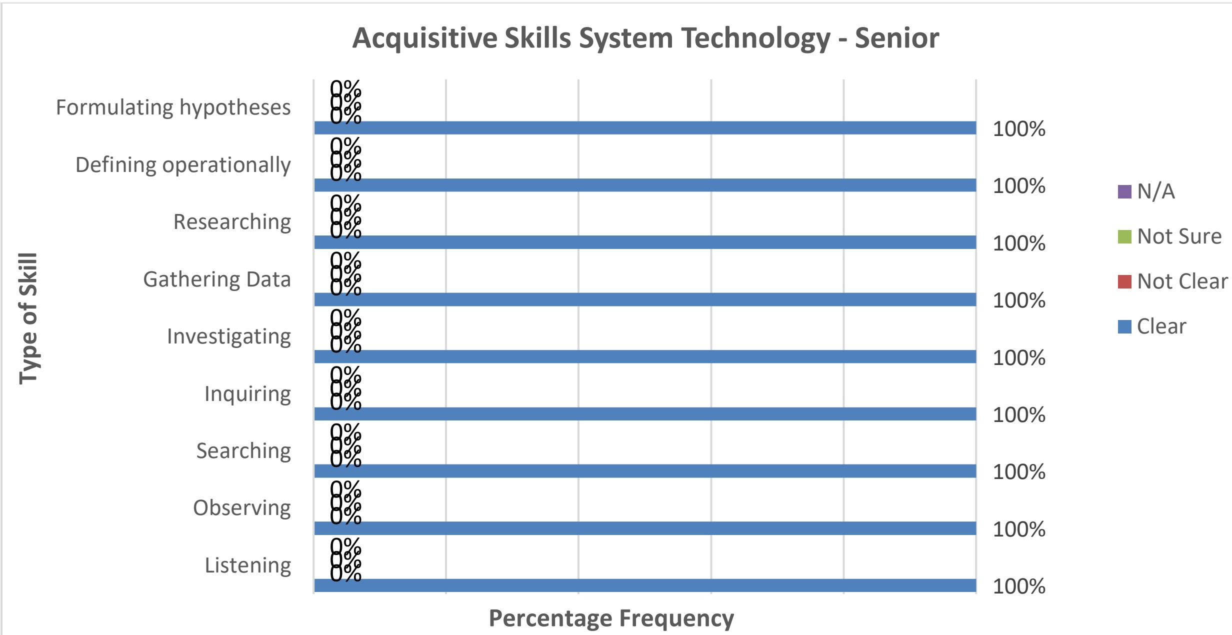


Figure 220: Acquisitive Skills Systems Technology

In the three cases of Junior Design and Technology, Senior Graphic Communication and System Technology, Figures 219, 220 and 221, respectively the results show two extreme cases from low performance to high performance. The implication of the findings is that generally learners, especially in Junior Design & Technology and Senior Graphic Communication, could not attain the envisaged status of being creative, critical and problem-solving with low abilities in gathering data, investigating and researching.

The challenges in skills acquisition may have emanated from the inadequate competencies and skills in teachers as facilitators who could not effectively engage learners. There is therefore, need for teachers of Design and Technology to understand the intentions and aspirations of the STEM Education Curriculum which emphasis on the learners taking the central position in their own learning. To this effect, there is need for enhancing inter-departmental professional interactions in order to share good practices which foster learner participation and engagement during teaching and learning.

b) Organizational Skills – Design and Technology

Figure 222 shows results in Organisational Skills for Design and Technology at Junior level. The findings disclosed that the skill of Organising was observed in 67% of the lessons while the rest of the skills were exhibited in 50% and less of the lessons monitored.

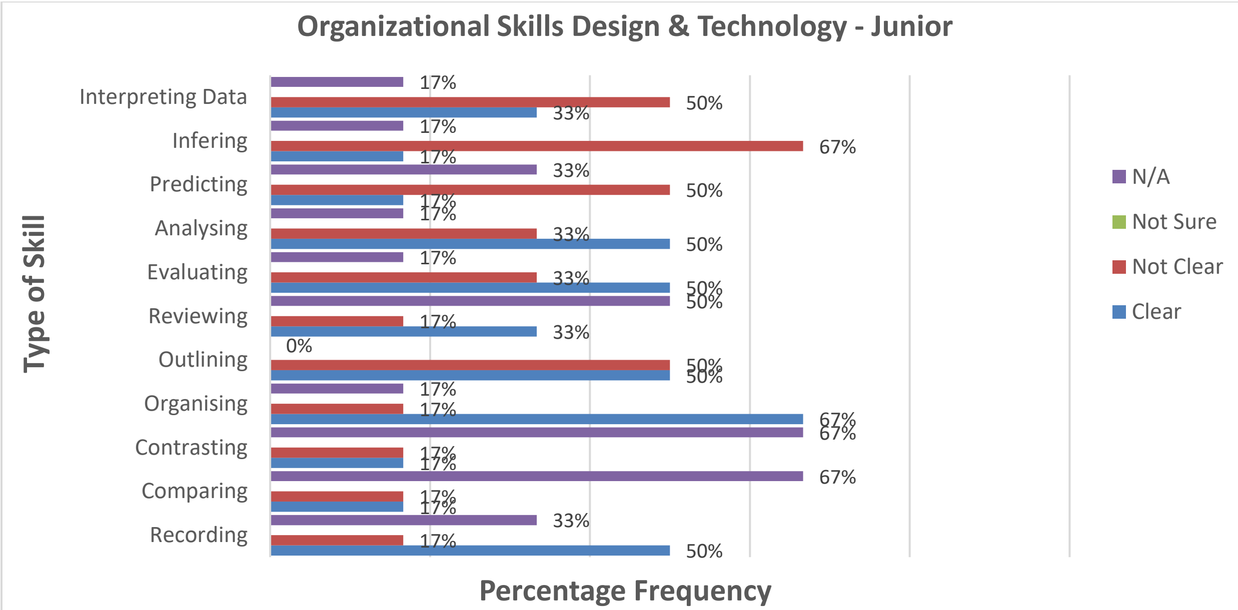


Figure 221: Organizational Skills Design & Technology - Junior

In Graphic Communication at Senior level, results in Figure 223 show that the skills of Recording, Organising and Outlining were observed in all the lessons monitored. The other skills of Comparing, Contrasting, Reviewing, Analysing and Interpreting Data were exhibited in 67% of the lessons while the rest of the skills were manifested in 33% of the lessons.

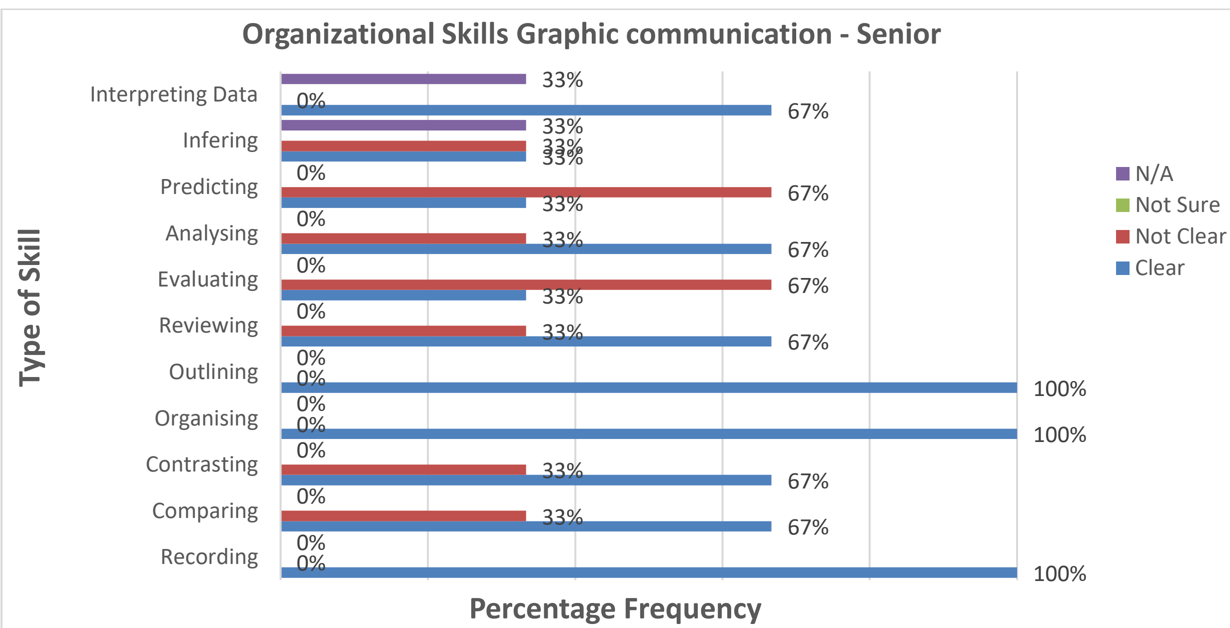


Figure 222: Organizational Skills Graphic communication – Senior

Figure 224 shows results in Organisational Skills for Senior System Technology lessons in Design and Technology which were observed during the survey. The findings indicated that 6 types of skills (Recording, Organising, Evaluating, Predicting, Inferring and Interpreting Data) were clearly observed in the lessons. The other 4 skills (Analysing, Reviewing, Outlining and Comparing) were not observed while the skill of Contrasting was not applicable.

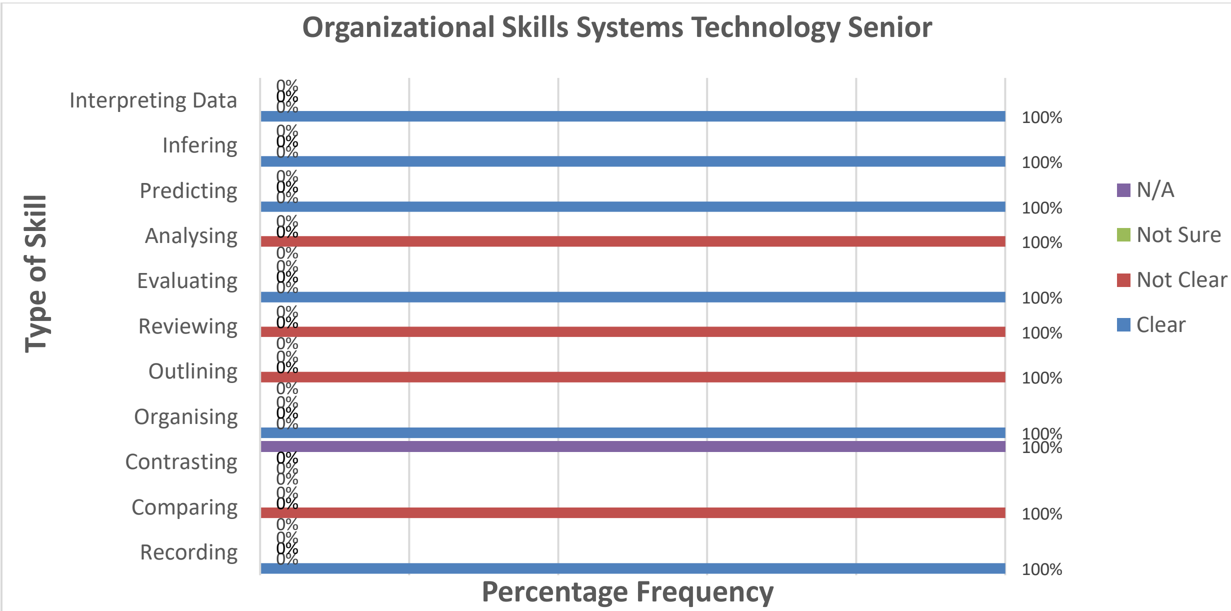


Figure 223: Organizational Skills - Systems Technology

The results show exposure of mixed Organisational Skills in the learners and in different lessons implying that in some lessons some learners exhibited some skills while in other lessons these skills were not observed. It also implies that the tasks that were given to the learners during the lessons might not have been adequately prepared to elicit some of these skills. However, the low abilities scored in certain skills as indicated in Figure 221, 223 and 224 need resolute steps to be taken to up-skill the teachers. This is in order for them to come to clear terms on the demands and aspirations of the STEM Education Curriculum so that they could in turn guide the learning appropriately. Arising from this, trainers of Curriculum implementers out to be proactive and pick the sticking points for use during training in order to help teachers be in the right perspective regarding intentions and aspirations of STEM Education in our country and beyond. Teachers can also make use of SBCPD activities to capacity build themselves on such issues as Organisational Skills.

c) Creative Skills – Design and Technology

Figure 225 shows Creative Skills results in Design and Technology for lessons observed at Junior level. The findings revealed that only the skill of Synthesising was clearly manifested in 17% of the lessons observed at this level. The rest of the Creative Skills were either not observed or not applicable.

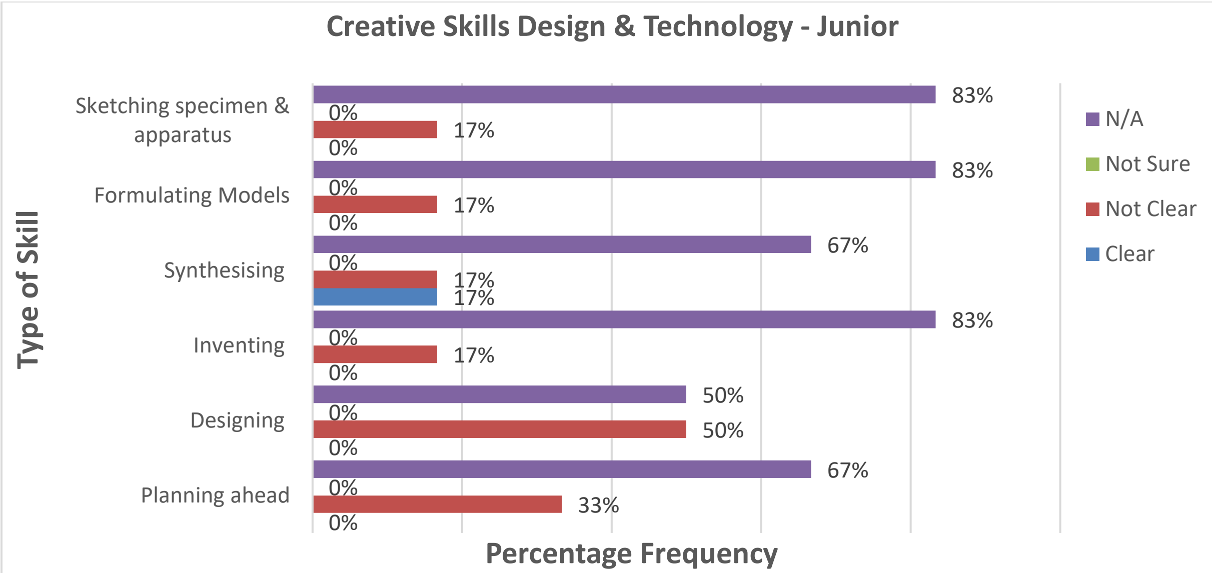


Figure 224: Creative Skills Design & Technology – Junior

Figure 226 shows results of Creative Skills in Graphic Communication at Senior level. The findings disclosed that 67% of the lessons observed manifested Designing skills, 33% exhibited skills of Inventing and Synthesising while the remaining skills were either not clearly observed or not applicable. There was uncertainty in 33% of the lessons regarding the skill of Synthesising implying that it was difficult to tell whether the skill could have been elicited or was not applicable in the lessons taught.

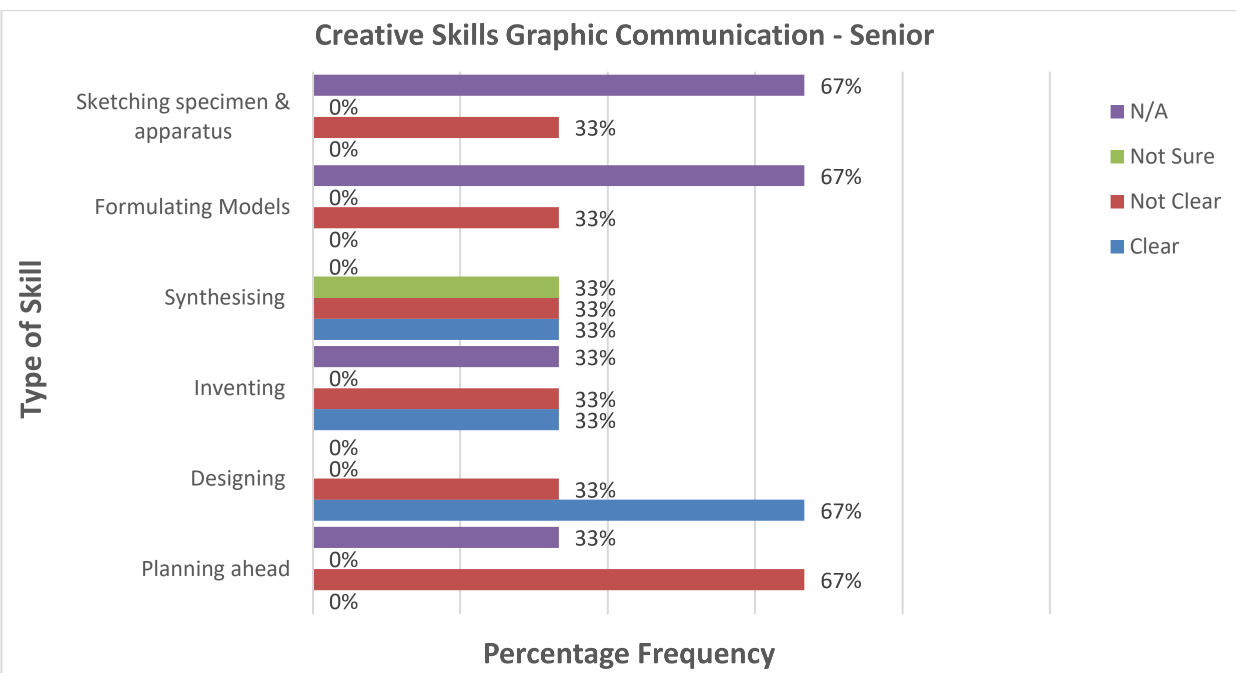


Figure 225: Creative Skills Graphic Communication – Senior

Figure 227 shows the results in System Technology of Senior Design and Technology for the lessons which were observed during the survey. The findings indicated that the skills of Designing and Synthesising were clearly exhibited in all the lessons observed. The skill of Inventing was not clearly observed while the rest of the skills were not applicable in the lessons monitored.

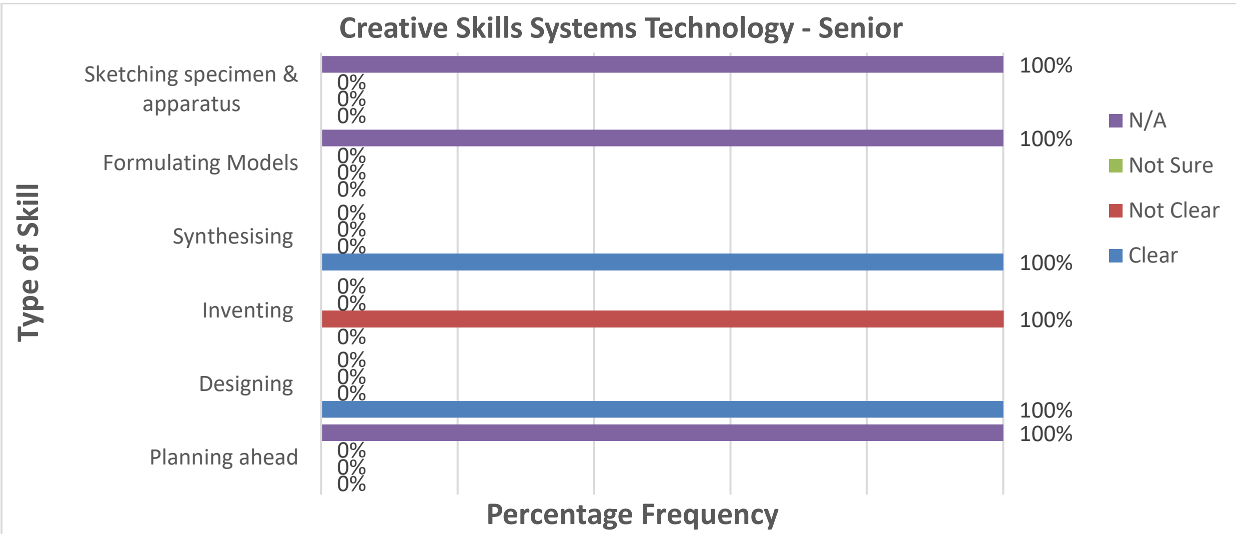


Figure 226: Creative Skills System Technology - Senior

The results for the three subjects, two at Senior level and one at Junior level, are conveying concerns looking at the number of skills which were scored as not clear and not applicable. Taking Design and Technology as overall learning area one would expect without second thought that Planning ahead, Designing, Formulating Models and Inventing should be a must considering the nature of the subject. This suggests that the teachers do not have adequate PCK to prepare appropriate tasks in line with the STEM Education to develop these important Creative Skills in the learners. The implications of these findings are that teachers will not be able to facilitate the attainment of the crucial skills which the subjects in Design and Technology demand for learners to have for self-employment and income generation. Arising from these findings, it is suggested that the teachers of Graphic Communication, System Technology and generally Design and Technology be capacity built in crucial aspects of the subjects in order to lift them from the old ways of teaching into the new ways of the aspirations of the Curricula.

d) Manipulative Skills – Design and Technology

Figure 228 shows Manipulative Skills results in Junior Design and Technology lessons. The findings revealed that the skills which were exhibited (Using, handling and maintaining instruments – 33%, Demonstrating – 17%, Constructing – 33%, Measuring and using number – 33% and Controlling variables – 17%) in the lessons were all below average. The other skills were either not observed or were not applicable.

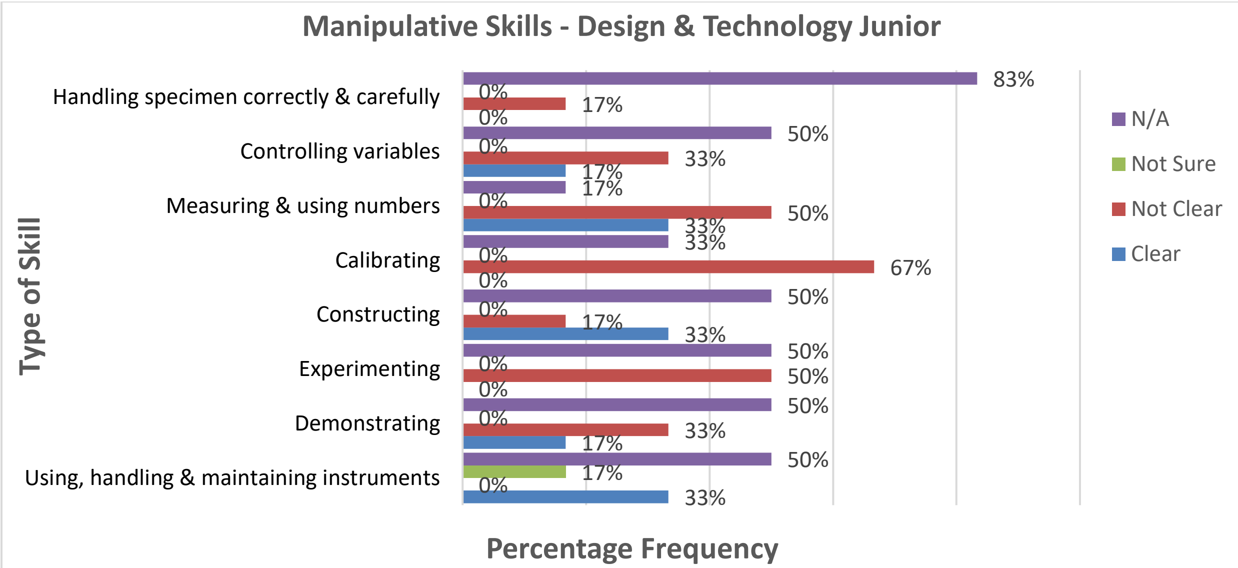


Figure 227: Manipulative Skills - Design & Technology Junior

The results for Manipulative Skills in Graphic Communication lessons of the Senior Design and Technology are as indicated in Figure 229. The findings disclosed that 5 types of Manipulative Skills (Using, handling and maintaining instruments, Demonstrating, Experimenting, Constructing and Controlling variables) were clearly exhibited in 33%, 33%, 17%, 33% and 17% of the lessons observed respectively. The remaining skills were not applicable in the lessons observed.

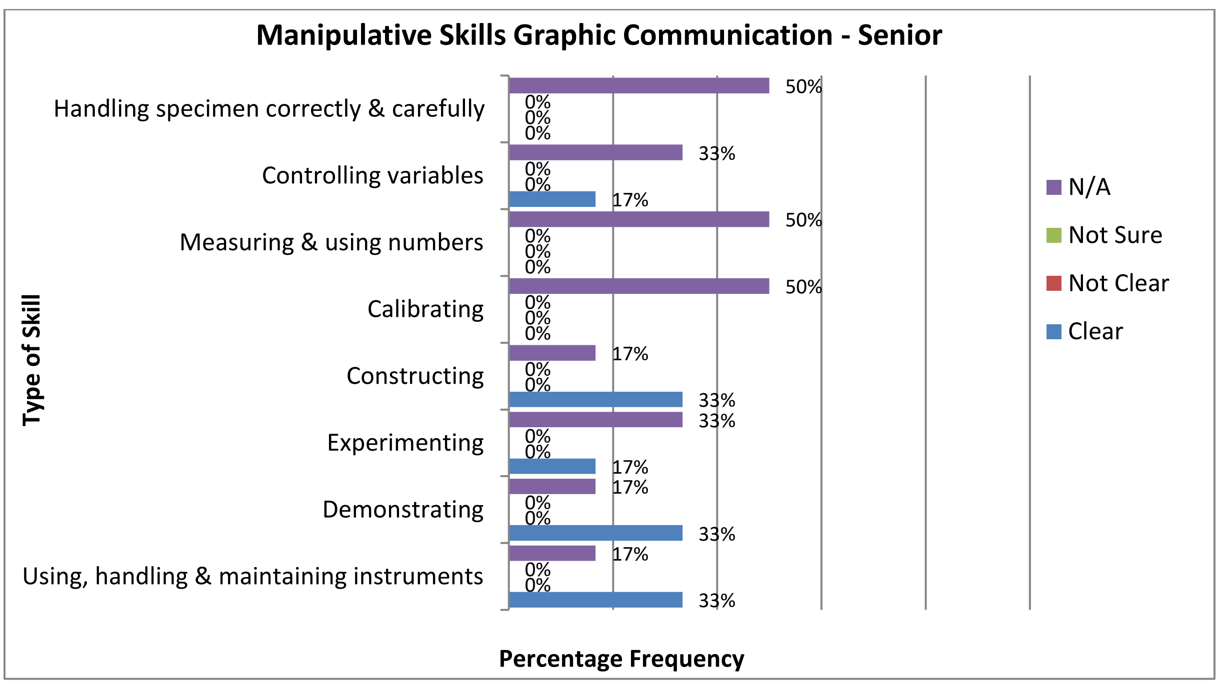


Figure 228: Manipulative Skills Graphic Communication – Senior

Figure 230 shows Manipulative results in System Technology of Senior Design and Technology lessons which were monitored during the survey. The finding revealed that all the lessons exhibited the skill of Constructing while the rest of the skills were either not clearly observed or were not applicable.

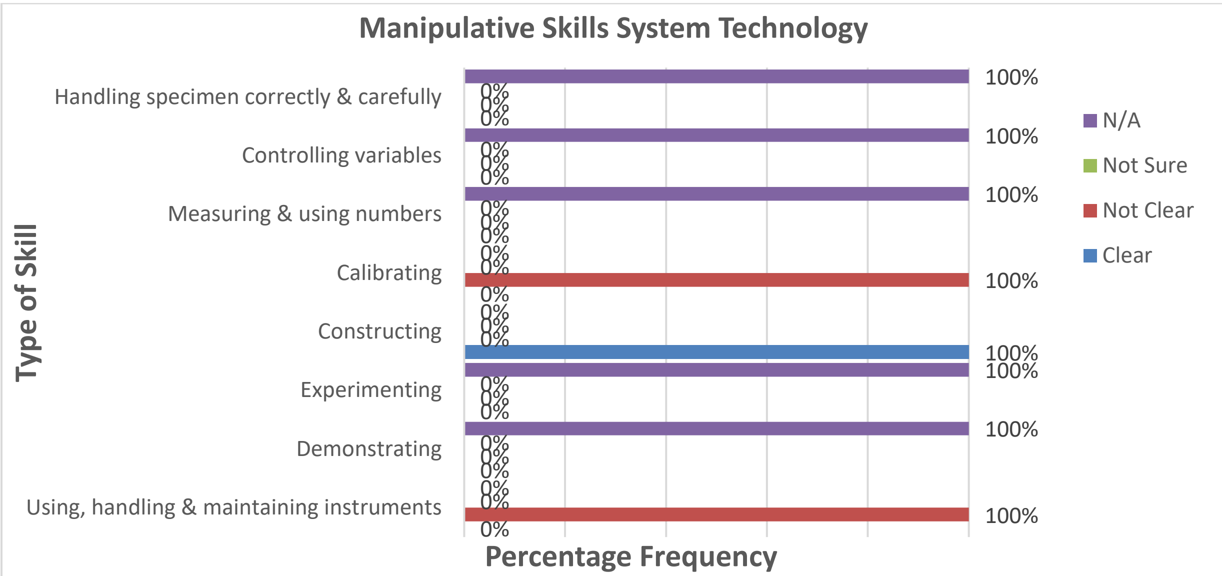


Figure 229: Manipulative Skills System Technology

The learners of Design & Technology generally from both Junior to Senior levels had very low scores in terms of the skills being clear. In Systems Technology only the skill of Constructing was clearly observed while the rest of the skills were either not observed or not applicable. This was the least expected phenomenon in this highly practical learning area. It might be possible that teachers prepared their lessons in the conventional way allowing only content mastery as opposed to skills attainment as could be seen by low percentages of skills being clearly observed. As a result, the engagement during teaching and learning to manipulate the materials might have been quite low and probably the kind and adequacy of teaching and learning materials which were considered at the point of preparing for the lessons. The implication of the observations made arising from the results would be that the Design and Technology learning area might not drive the change being championed in STEM schools of skills-based teaching and learning for job creation and value addition. To this effect, STEM teachers would require shifting from the old practices to the ones that are stipulated in the STEM Education Curriculum if meaningful Manipulative Skills are to be realised in the learners. Furthermore, the nature and utilization of the teaching and learning materials require a new approach in terms of choice and plan for utilization for both teachers and learners. Therefore, CPD activities, both school-based and otherwise are required to capacity-build the teachers in these skills and proper planning for lessons.

e) Communicative Skills – Design and Technology

Figure 231 shows results on Communicative Skills in Junior Design and Technology lessons which were observed during the survey. The findings indicated that the skills of Questioning, Discussing and Reporting were clearly observed in all the lessons, Explaining, Writing and Communicating were observed in 83% of the lessons, Teaching and Critiquing in 67% and 50% of the lessons respectively. It was observed that the skill of Graphing was not observed in any of the lessons.

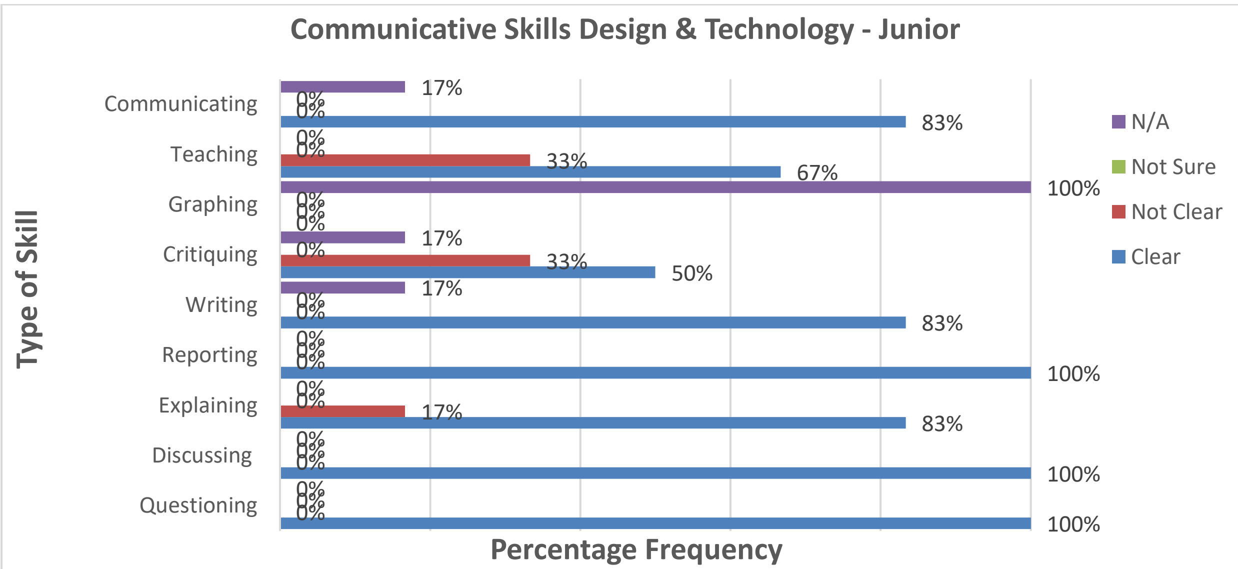


Figure 230: Communicative Skills Design & Technology – Junior

The results of Communicative Skills in Senior Graphic Communication of the Design and Technology are as shown in Figure 232. The findings revealed that 5 out of 9 Communicative Skills were exhibited in all the lessons observed. Further, the skills of Reporting, Critiquing and Teaching were clearly observed in 67% of the lessons while learners displayed Graphing skills in 33% of the lessons.

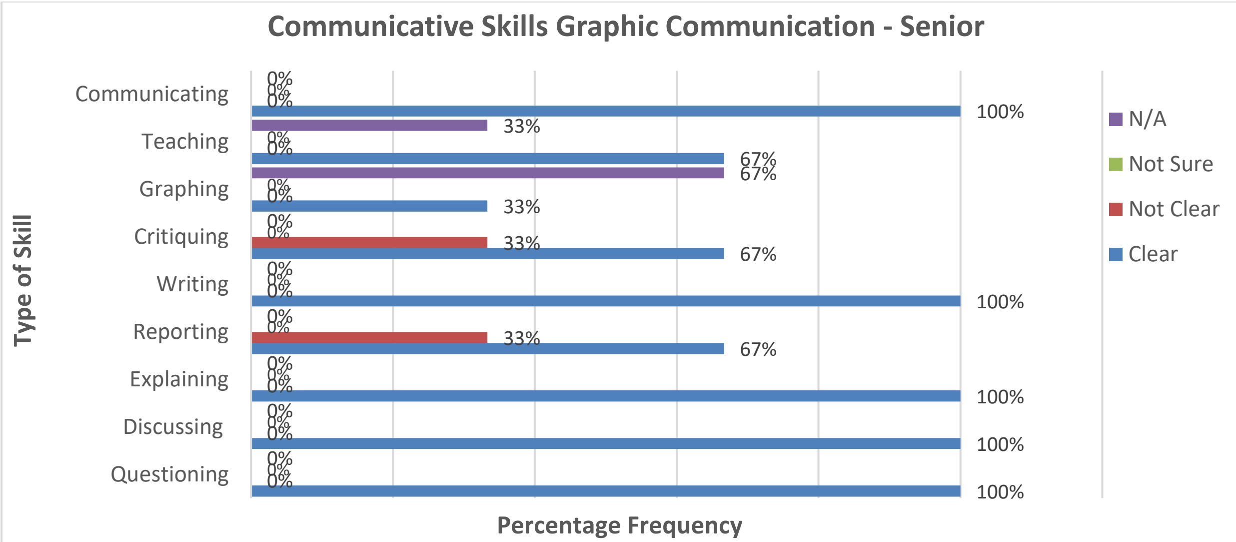


Figure 231: Communicative Skills Graphic communication – Senior

Figure 233 shows results in Communicative Skills for Systems Technology of Senior Design and Technology lessons observed. The findings indicated that 6 out of 9 Communicative Skills were clearly observed in all the lessons while the other 3 skills (Critiquing, Graphing and Teaching) were not observed.

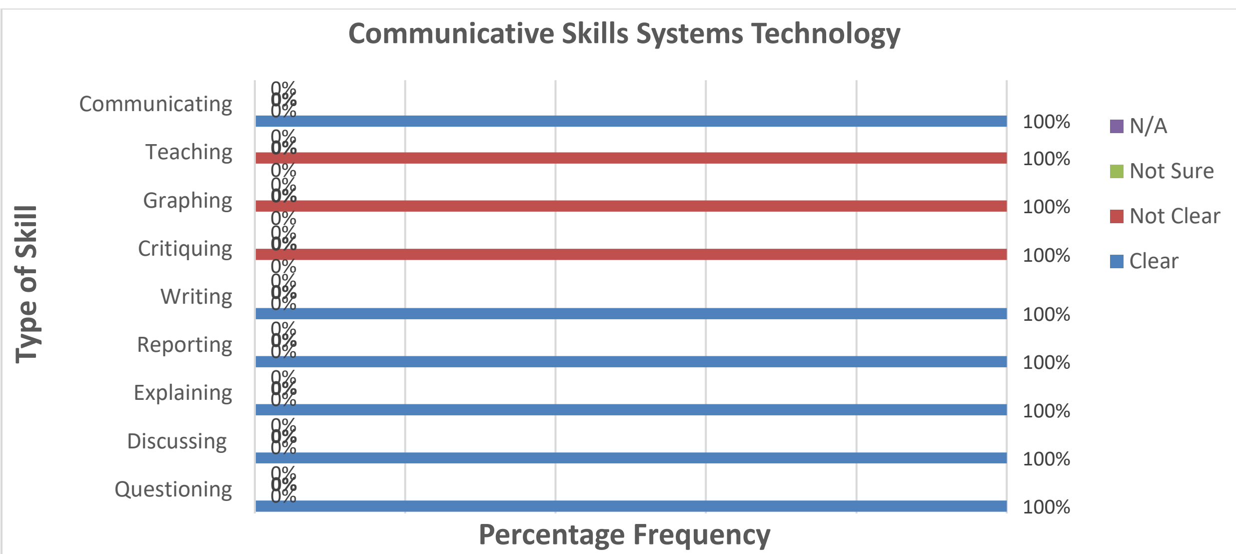


Figure 232: Communicative Skills Systems Technology

The results show that Communicative Skills in Design and Technology at both Junior and Senior levels were generally well taken care of. However, Critiquing, Graphing and Teaching skills were consistently not well handled at both levels. This shows that the type of communication exhibited by learners was one way, with little opportunity for critiquing amongst the learners. These skills are crucial in communicating products because they help in value addition and improvement of the final product. The low Graphing skills observed in the lessons might have arisen from the nature of the lesson activities that could not permit plotting or sketching graphs during teaching and learning. The implications of these findings are that learners would not be able to develop the skills of Critiquing, Teaching and Graphing if they are not exposed to such during the teaching and learning process. This has an effect on the research process where the learners are required to defend their research works as they might not be able to communicate effectively and receive constructive feedback assertively. Therefore, teachers should strive to engage learners in order to develop these skills.

4.1.15.6.Hospitality & Tourism

a) Acquisitive Skills

Figure 234 shows results in Acquisitive Skills for Hospitality and Tourism at Junior level. The findings indicated that all the Acquisitive Skills except for the skills of Defining operationally and Formulating hypotheses were clearly observed in all the lessons at this level.

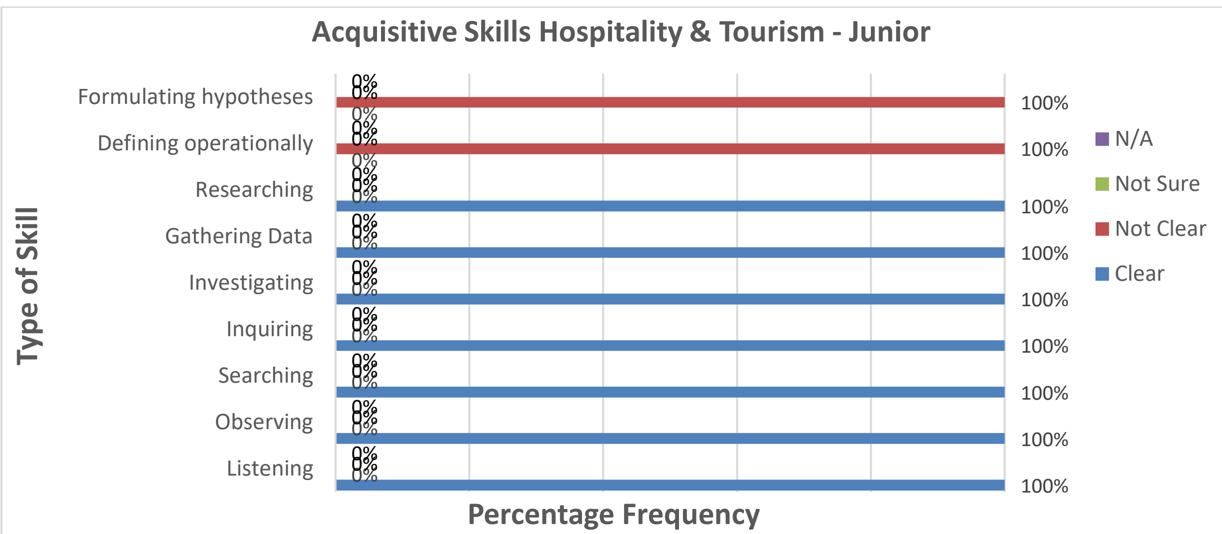


Figure 233: Acquisitive Skills Hospitality & Tourism - Junior

At Senior level, the results for the same subject are shown in Figure 235. Like the observations made at Junior level, the findings at Senior level indicate that all the Acquisitive Skills except for the skill of Defining operationally and Formulating hypotheses were clearly observed in all the lessons.

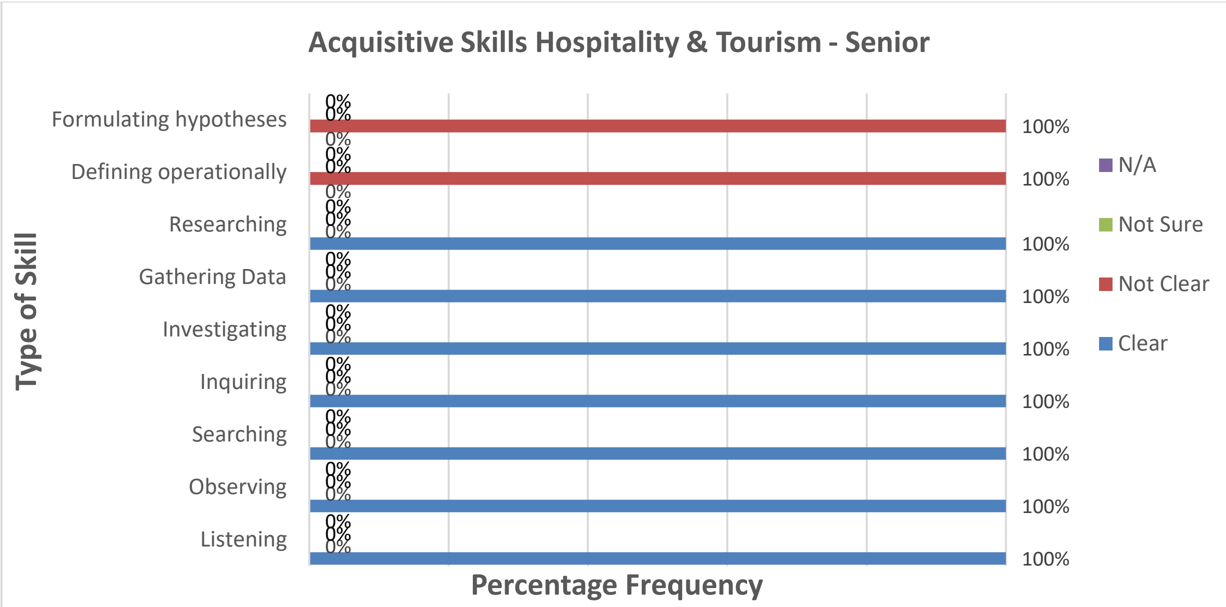


Figure 234: Acquisitive Skills Hospitality & Tourism - Senior

From the results at both Junior and Senior levels it was observed that the only skills that were not exhibited were the Defining operationally skills and the Formulating hypotheses skill. The rest were clearly observed. These results are an indication that learners at both grade levels had enhanced abilities for acquisitive skills which was a good sign for the efforts that their teachers were putting in for effective teaching and learning. Nevertheless, the fact that the skills of Formulating hypotheses and Defining operationally were not observed at both levels should be a source of concern to the teachers, learners and other stakeholders. This is because learners ought to develop abilities to state the expected outcomes and how to measure variables in research. Defining operationally also helps learners to put the task in context. To this effect, teachers need to strive to develop these skills in learners for them to be able to hypothesize the possible solutions before the actual research or experiment is carried out.

b) Organizational Skills

Except for the skills of Contrasting and Evaluating, the results in Organisational Skills at Senior level showed that all the other skills were clearly observed in all the lessons as indicated in Figure 236.

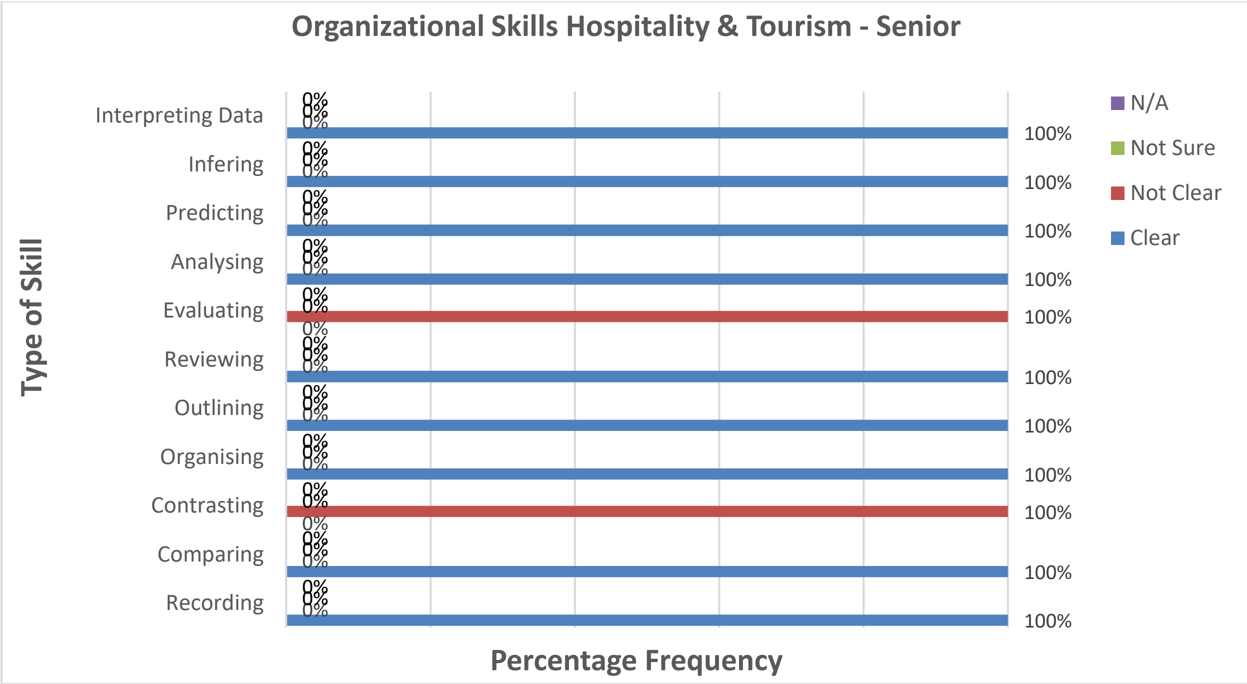


Figure 235: Organizational Skills Hospitality & Tourism – Senior

Figure 237 shows results in Organisational Skills at Junior level for Hospitality and Tourism as observed in the lessons. The findings indicated that all the Organisational Skills were clearly exhibited in all the lessons observed.

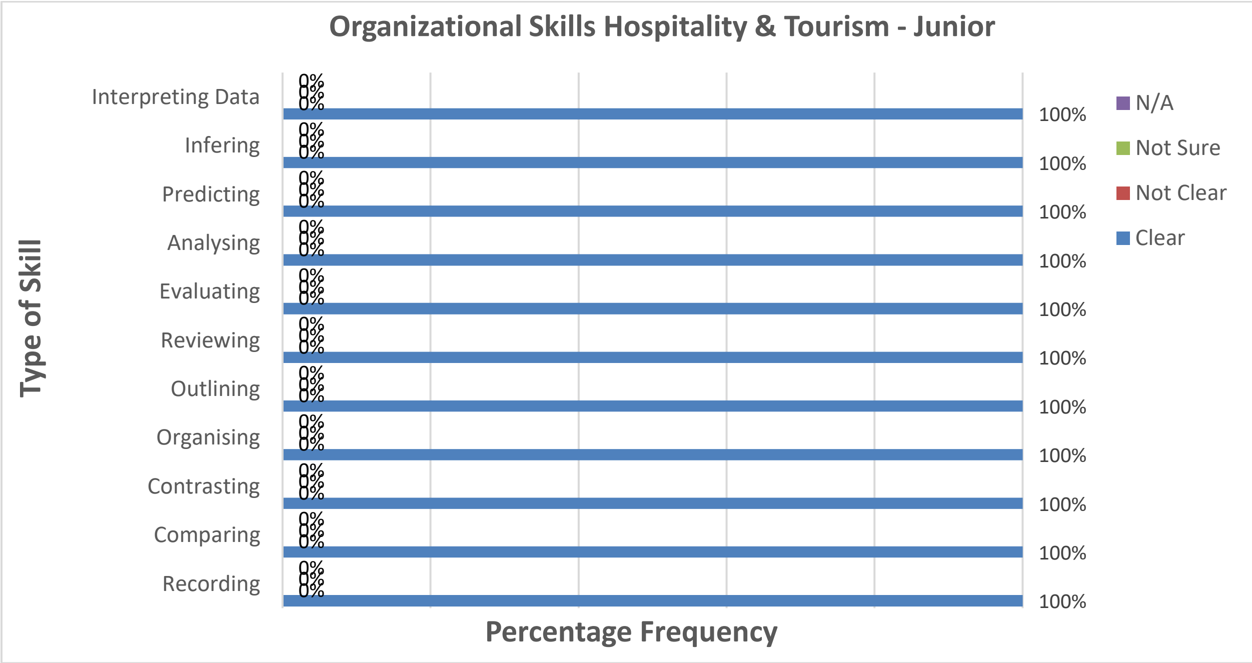


Figure 236: Organizational Skills Hospitality & Tourism - Junior

The remarkable acquisitive skills results observed at junior and senior levels are an indication that the lesson activities planned for and delivered were able to solicit for learners' capacity to manage and stay focused on different tasks. However, at senior level the absence of the skills of contrasting entails that learners were deprived of the ability to determine differences between and among objects. Further, the absence of the skill of evaluating at senior level raises concern too as it means that the lesson activities did not have the ability to foster reasoning of arguments and explanations. Evaluation is a key aspect in STEM teaching and learning as it helps learners to make logical judgements as they do their research. The implication of this is that learners might not learn how to make appropriate judgements during and after the learning process. In this regard, teachers need to plan for activities that encompass the exploration of all Organisational Skills.

c) Creative Skills

Figure 238 shows results in Creative Skills for Hospitality and Tourism at Senior level from the lesson observed during the survey. The findings revealed that only the skills of Planning ahead and Synthesising were clearly exhibited in all the lessons while the rest of the skills were not observed.

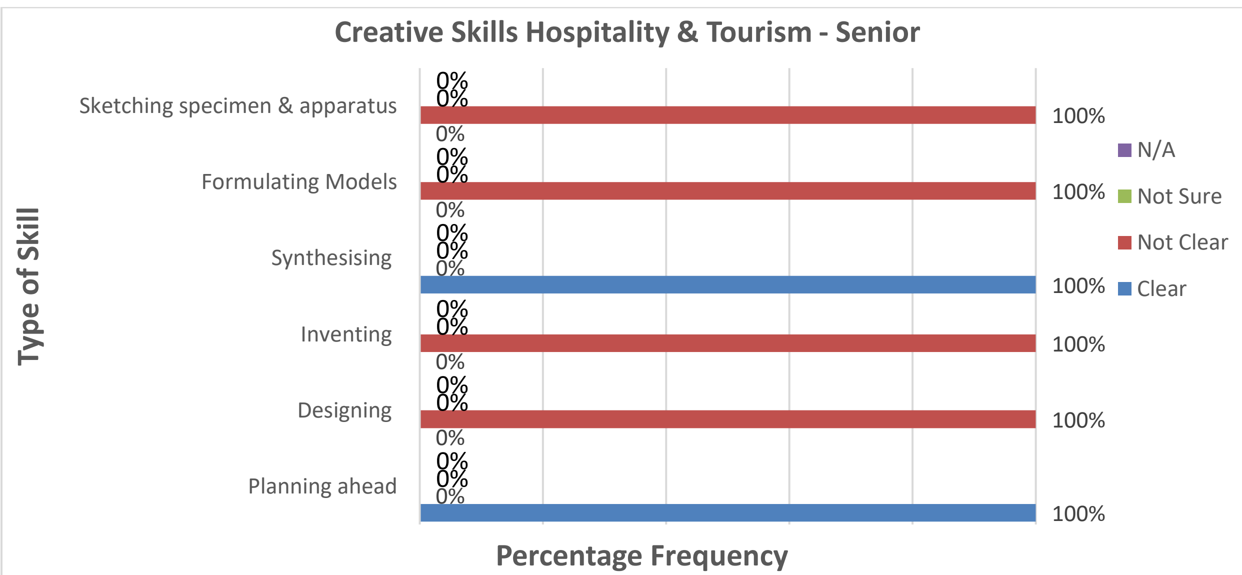


Figure 237: Creative Skills Hospitality & Tourism – Senior

At Junior level, the results for Creative Skills in Hospitality and Tourism indicated that all the skills were clearly observed in all the lessons monitored during the survey, except for the skill of Sketching specimen and apparatus as shown in Figure 239.

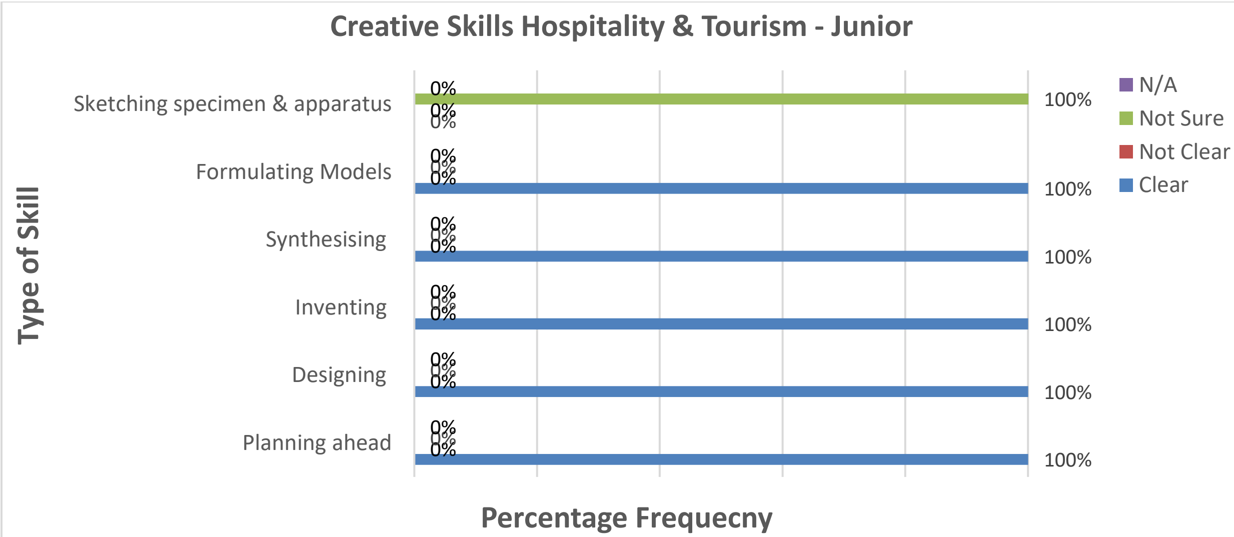


Figure 238: Creative Skills Hospitality & Tourism - Junior

The outstanding Creative Skills observed in the Junior Hospitality and Tourism lesson are an indication that the lesson activities provided opportunities for learners to plan ahead, design, and synthesise the issues on stories to do with tourism. Learners at Senior level could only show noticeably two types of skills which were the planning ahead and synthesizing even when it was evidently clear that the rest of the skills were absolutely applicable with the materials readily available though no equipment for their use was in sight. The results suggest that the activities that the learners were made to undertake did not provide opportunities for them to display the all the skills. This in itself was a limiting factor in as far as development of creative skills is concerned. The skills that were not explored are critical in promoting innovativeness and inventiveness in learners. The reason for this inadequate exploration of key skills that should drive STEM Education is that teachers themselves did not have adequate competencies and skills to plan and deliver lessons that foster creativity. The implication of this is that learners would not only be unable to develop strategies on how to accomplish goals but also not develop new ideas and products. To remedy this situation, it is proposed that customised CPDs for teachers of Hospitality and Tourism be strengthened and the intensive study of teaching and learning materials should be central in these capacity building trainings at all levels.

d) *Manipulative Skills*

Figure 240 shows results for Manipulative Skills in Hospitality and Tourism at Senior level for the lessons observed during the survey. The findings indicated that only the skill of Demonstrating was clearly manifested in the learners in all the lessons observed while the other skills were either not observed or not applicable.

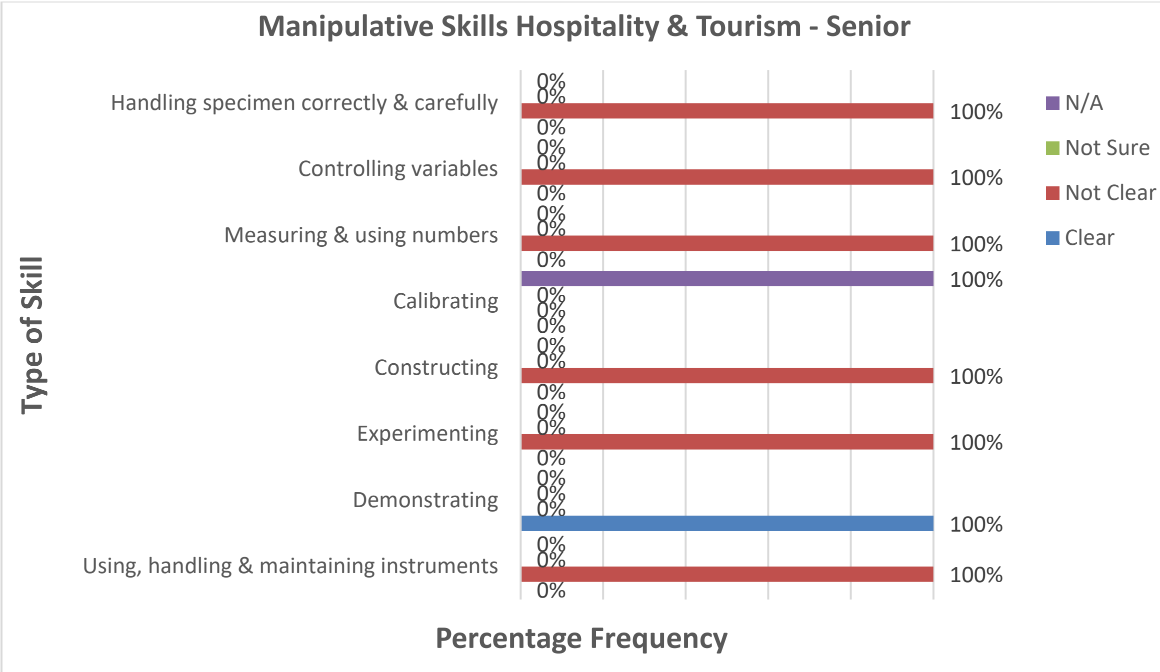


Figure 239: Manipulative Skills Hospitality & Tourism - Senior

At Junior level, the Manipulative Skills results in Hospitality and Tourism show that the skills of Demonstrating, Controlling variables and Handling specimen correctly and carefully were clealry exhibited in all the lessons while the rest of the skills were shrouded in uncertainty as shown in Figure 241.

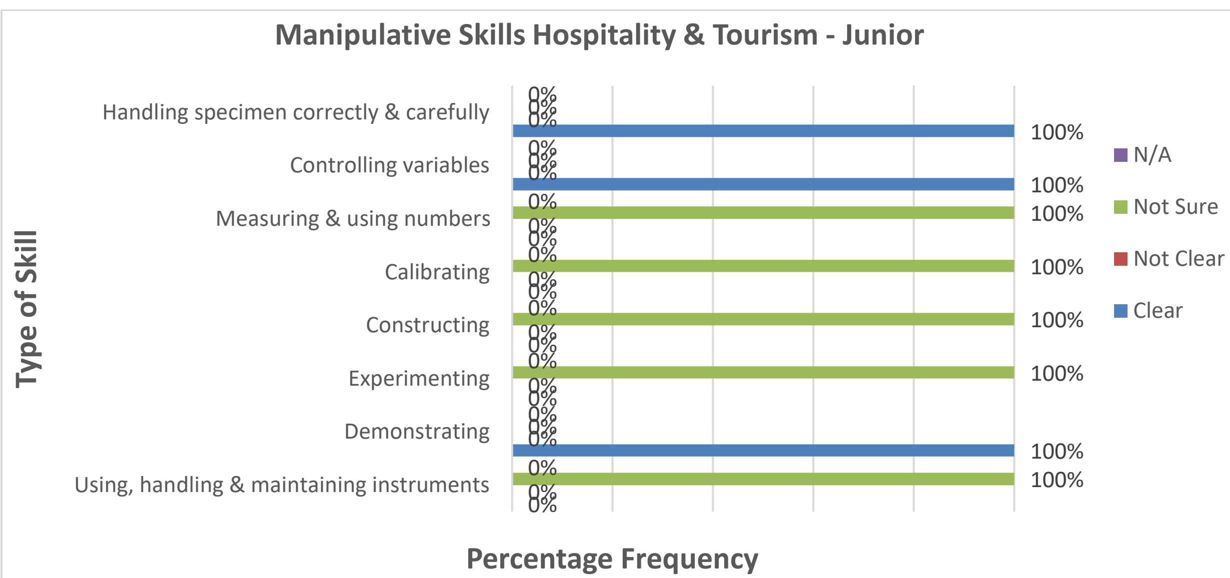


Figure 240 Manipulative Skills Hospitality & Tourism - Junior

Other than Demonstrating for both Junior and Senior and Controlling variables and Handling specimen correctly and carefully, the other types of skills under Manipulative category were not impressive at both levels as they recorded not clear, not applicable and not sure. Hospitality and Tourism is a manipulative subject in itself because most of the concepts involve creativity and manipulation of products. Therefore, it was expected to see a lot of manipulative activities in the lessons observed. The reason for these results seen in Manipulative Skills could be as a result of following the teaching and learning materials that might have misled the teachers. A case in point is a lesson at Junior level on *Home*. The concept in the text book used was not written in the context of "*home*" but rather *House*. This resulted in misunderstanding the concept and eventually the Manipulative Skills could not be exhibited. There is need, therefore, for teachers to engage in intensive study of teaching and learning materials, including research, in order to interpret the Curriculum intentions appropriately and plan activities which would help learners to develop Manipulative Skills.

e) Communicative Skills

At Senior level, the results are same as those for Junior lessons as can be seen in Figure 242. The findings revealed that all the skills were clearly exhibited in all the lessons observed, except for the skill of Graphing which was not applicable in those particular lessons.

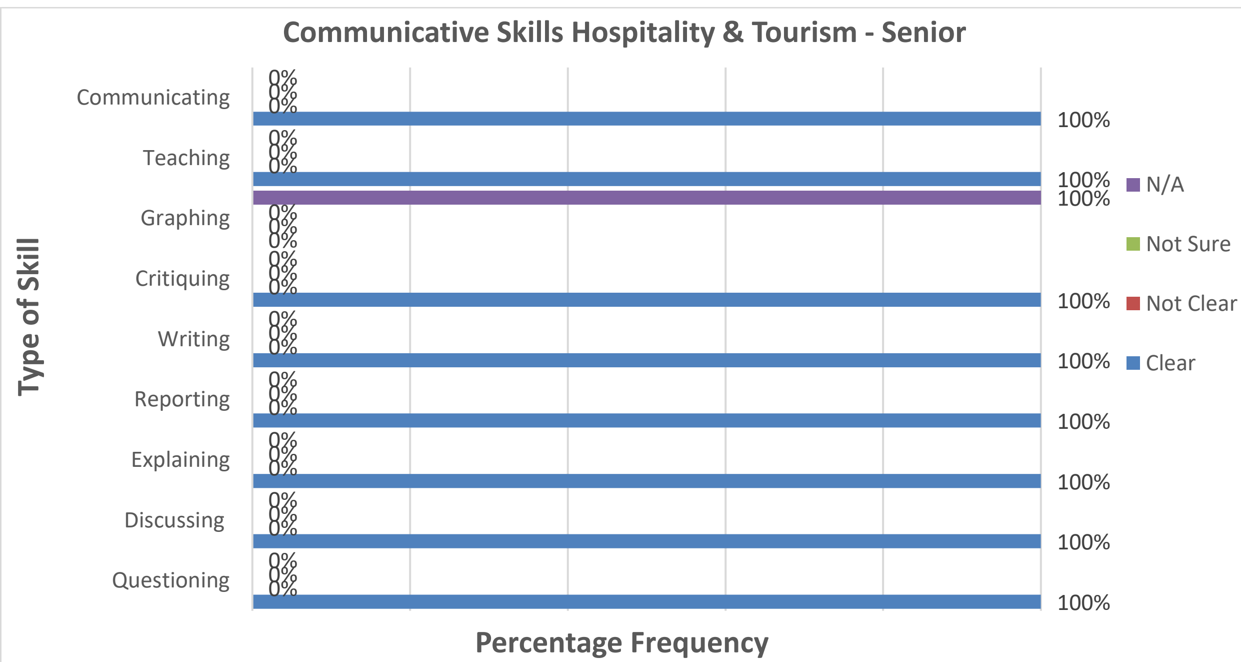


Figure 241: Communicative Skills Hospitality & Tourism – Senior

Figure 243 shows results in Junior Hospitality and Tourism for the lessons observed during the survey. The findings revealed that all the skills, except for the skill of Graphing, were clearly exhibited in all the lessons observed.

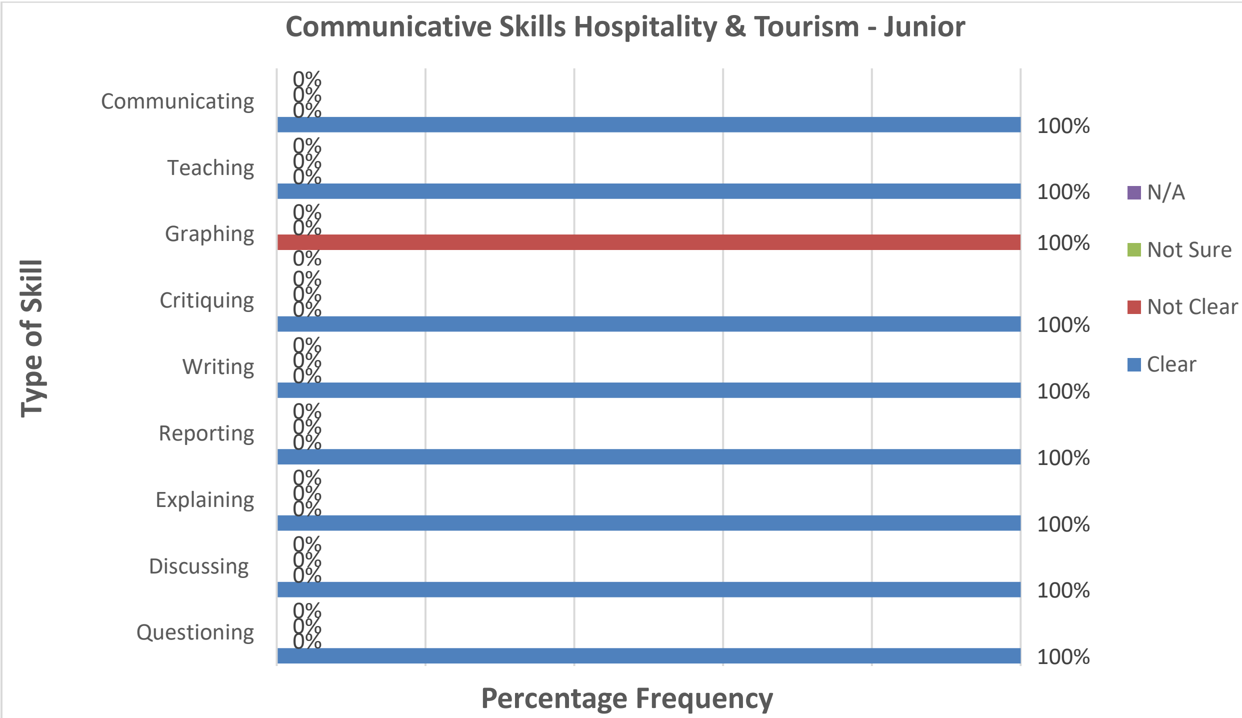


Figure 242: Communicative Skills Hospitality & Tourism - Junior

The display of almost all Communicative Skills in lessons at both levels shows that the learners were provided with the opportunity to communicate with one another during the lessons. The implication is that learners were ready to take learning as their responsibility and that they should be given even greater opportunities to farther the learning experiences. In order to achieve this exploit, more mind provoking questions for their extended discussions should be made available in the lessons during the planning for lessons as well as the follow up questions during the teaching learning processes. It is also imperative to include tasks that graphing so as to develop this skill in learners.

4.1.15.7.Mathematics

a) Acquisitive Skills

Figure 244 shows results of Acquisitive Skills for Mathematics lessons observed at Senior level. The findings disclosed that the skill of Listening was more prominent in all of the observed lessons whereas in 60% of the lessons the skills of Observing and Inquiring were displayed. The other remaining Acquisitive Skills were exhibited in 40% of the lessons and only 20% of the lessons displayed the skill of Defining operationally.

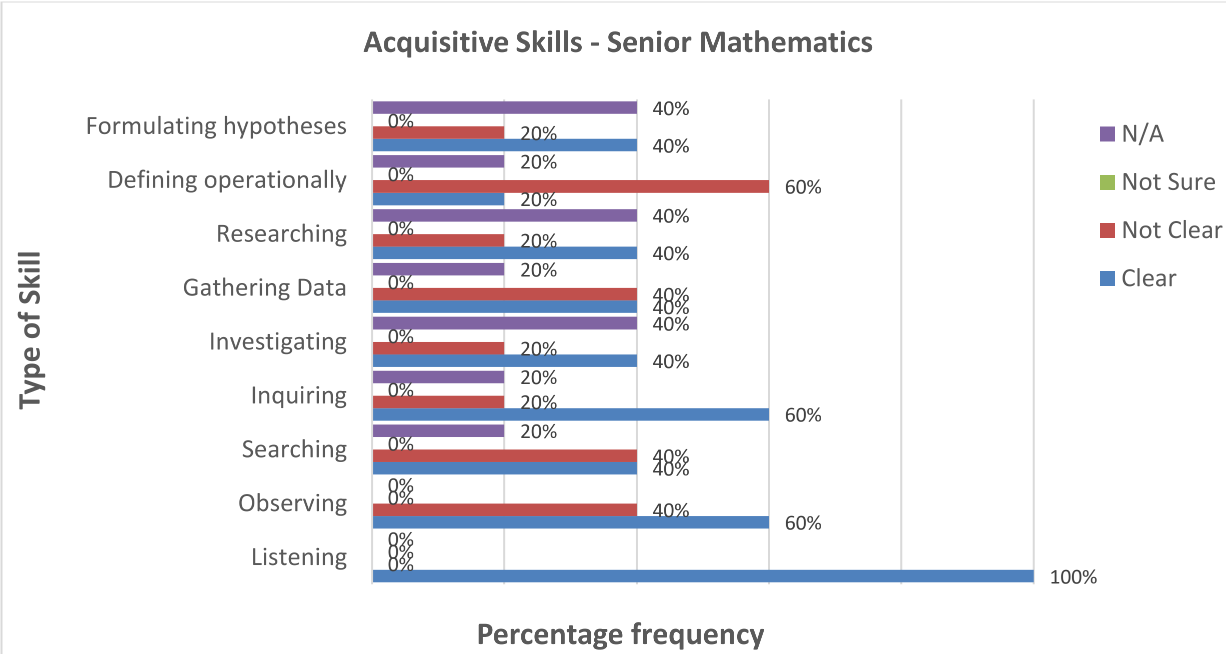


Figure 243: Acquisitive Skills - Senior Mathematics

The Mathematics Acquisitive Skills results observed in Junior Secondary lessons are shown in Figure 245. The findings revealed that 5 out of the 9 Acquisitive Skills were exhibited in all the lessons, 2 (Investigating and Researching) were present in 83 % of the lessons while the other 2 skills (Formulating hypotheses and Defining operationally) were displayed in 67 % and 50 % respectively of the lessons observed at this level.

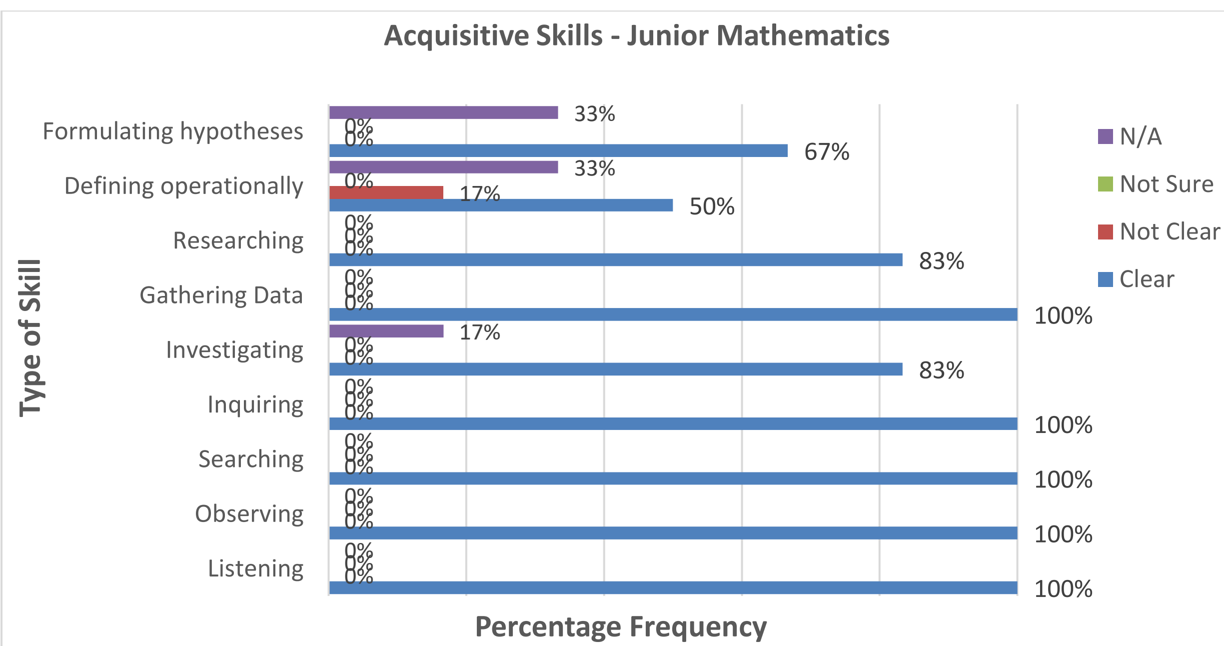


Figure 244: Acquisitive Skills - Junior Mathematics

The results showed that learners at Junior level were observant and displayed inquiring skills. This might have been as a result of the captivating nature of lesson activities that allowed learners to engage in inquiry and observation actions. Learners were also able to gather as much information as possible from the activities. However, Defining operationally and Formulating hypotheses were still a challenge in some lessons. At Senior level, most of the lessons did not exhibit a number of Acquisitive Skills. This could be due to the limiting nature of the tasks which did not provide learners with the opportunity to develop such skills. The implication of these deficiencies is that learners would find it difficult to effectively organise the data and come up with an appropriate product. It may also result in non-achievement of the STEM Education Curriculum objectives in producing CCAT learners. Learners might not develop critical minds without acquiring investigative skills during their learning processes. To this effect, learners need to be engaged more in investigating by exposing them to higher order questioning which would provoke investigative abilities as they seek ways of responding to the given tasks either individually or in manageable and consciously formed groups. It is at this point that the STEM teachers need refined skills in formulating key questions and organising appropriate scenarios which should prompt learners to begin to think on how to find the way out of a problem or challenge. Therefore, teachers should strive to carry out rigorous study of teaching and learning materials in order to come up with appropriate activities for the learners.

b) Organizational Skills

At Senior level, the Organizational Skills results as shown Figure 246 indicate that the Recording, Contrasting and Analysing skills were observed in all Mathematics lessons, 4 skills were demonstrated in 80% of the lessons while the remaining 4 Organisational Skills of Outlining, Reviewing, Predicting and Inferring were shown in 60% of the lessons.

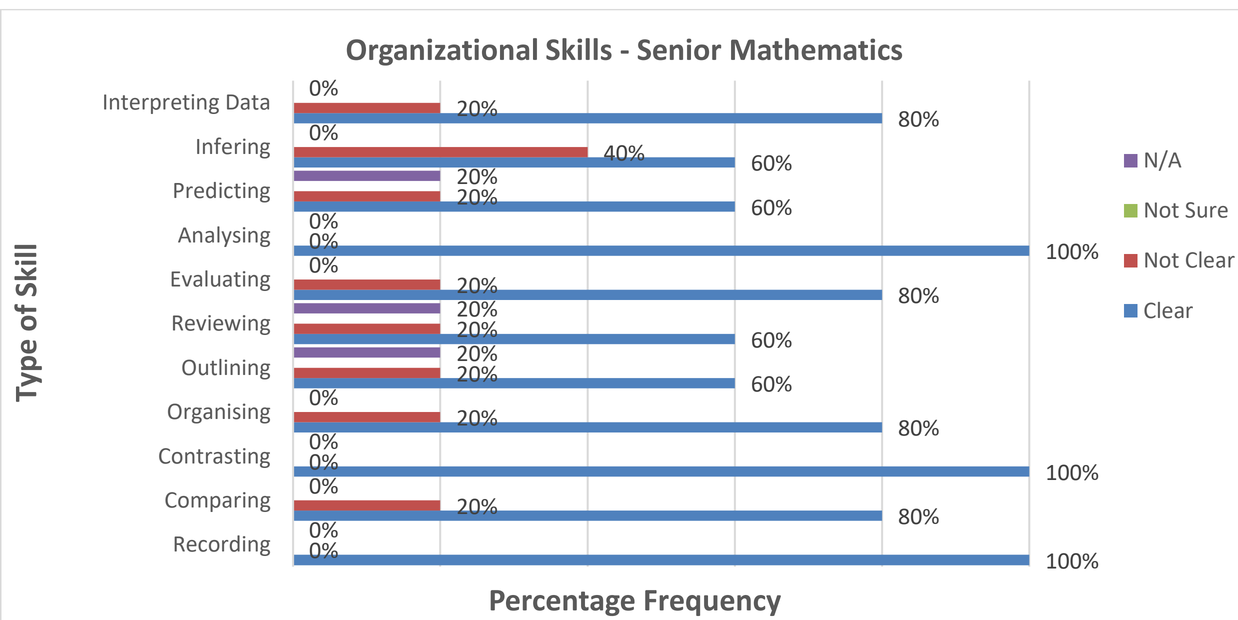


Figure 245: Organizational Skills - Senior Mathematics

Figure 247 shows results on Organisational Skills observed in Mathematics lessons at Junior level. The results indicate that 4 out of 11 skills were displayed by learners in all the lessons, 6 skills were shown in 83% of the lessons, while the Outlining skill was exhibited in 67% of the lessons.

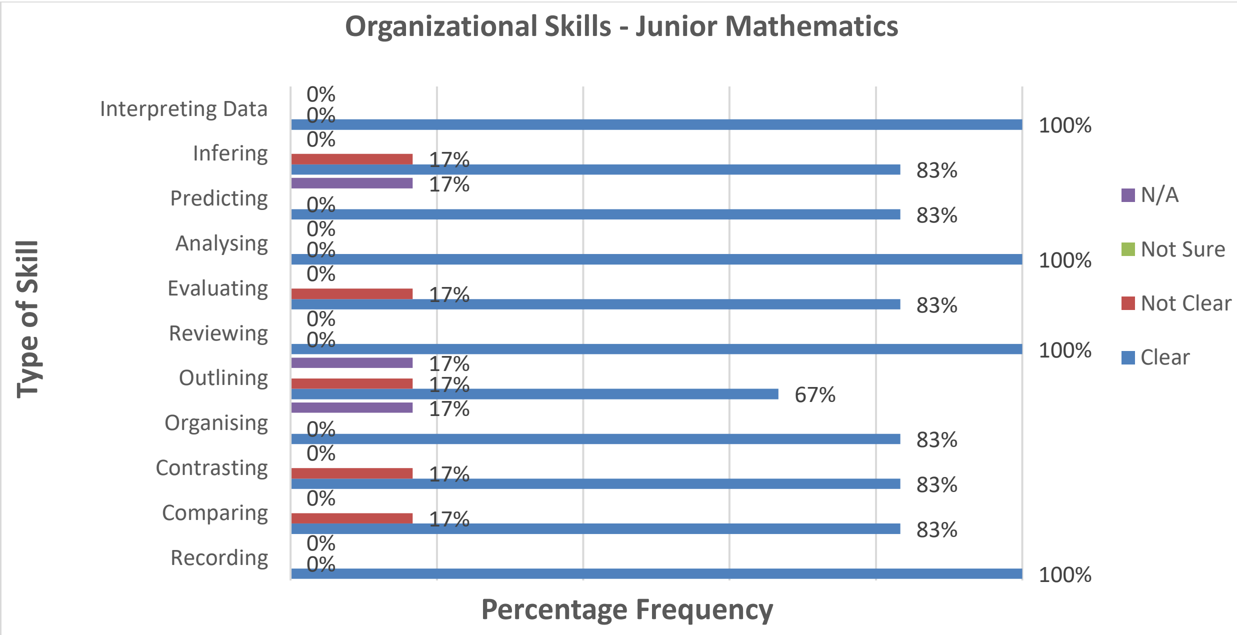


Figure 246: Organizational Skills - Junior Mathematics

The high levels of organizational skills may be attributed to the teacher factor in that the pre-STEM teaching training conducted for five days gave them some insights into the kind of learners expected in STEM Schools. To this effect, teachers might have instilled and inculcated into learners the expectations of the Curricula which the learners were to interact with during their learning processes. This might have given learners the impetus to be recording, comparing, contrasting, reviewing, predicting, analyzing, evaluating and interpreting their data in an organized way. Moreover, learners could have been thrilled by the new ways of doing some things by teachers where encouragement was given for learners to engage in activities as much as they could and also bring in their own suggestions and ideas. Another attribute could be the appropriate selection of tasks and activities that teachers prepared for their learners which prompted the display of Organisational Skills. For the skills that were lowly performed it is encouraged that teachers find strategies of developing them in learners. This can be achieved through collaborative planning or through involvement in Lesson Study and other CPD activities.

c) Creative Skills

For the Creative Skills at Senior level, the results observed in Mathematics lessons indicate that Planning ahead, Designing, Synthesising and Formulating models were demonstrated in 20% of the lessons. The rest of the skills were either not observed or not applicable as shown in Figure 248.

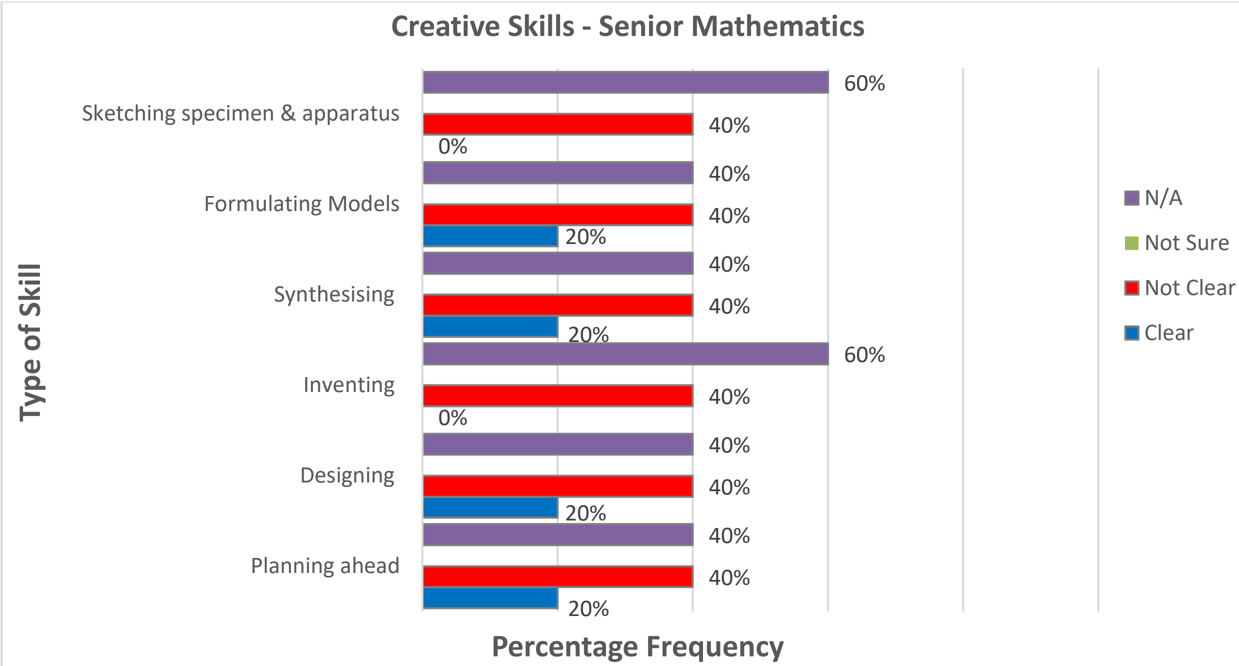


Figure 247: Creative Skills - Senior Mathematics

Figure 249 shows results on Creative Skills observed in Mathematics lessons at Junior level. The findings disclosed that the skills of Designing, Synthesising and Planning ahead were observed in 83%, 67% and 50% of the lessons respectively while the skill of Formulating models was exhibited in 33% of the lessons and that of Sketching specimen and apparatus was demonstrated in 17% of the lessons. None of the lessons displayed the skill of Inventing.

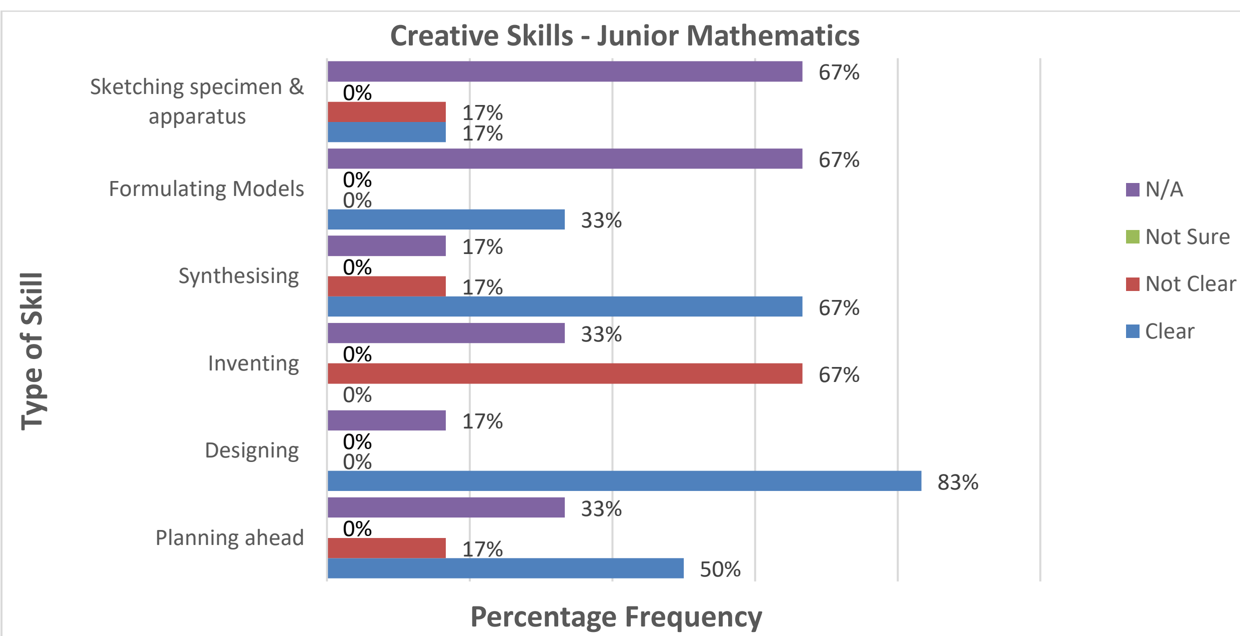


Figure 248: Creative Skills - Junior Mathematics

It was observed that at Junior level only 3 skills were prominent while the others were below average. At Senior level all the skills were below average. The aim of STEM Education is to develop learners who are CCAT and Mathematics plays a big role in achieving this aim. Therefore, the development of Creative Skills in learners should be taken as a priority by teachers as they plan the activities for the learners. The results above show that the teachers did not understand the dictates of the STEM Education Curriculum and hence did not prepare adequately for their lessons. This has an effect on the research activities that the learners would be engaged in as they would not be able to invent and formulate models. There is need for more capacity building of teachers in this regard for them to enhance their PCK. This can be achieved through SBCPD and other activities.

d) Manipulative Skills

Figure 250 shows results of Manipulative Skills observed in Senior Mathematics lessons. The results indicate that the skill of Measuring & using numbers was exhibited in 40% of the lessons while the skills of Experimenting, Constructing and Controlling variables were exhibited in 20% of the lessons observed. The rest of the skills were either not observed or not applicable.

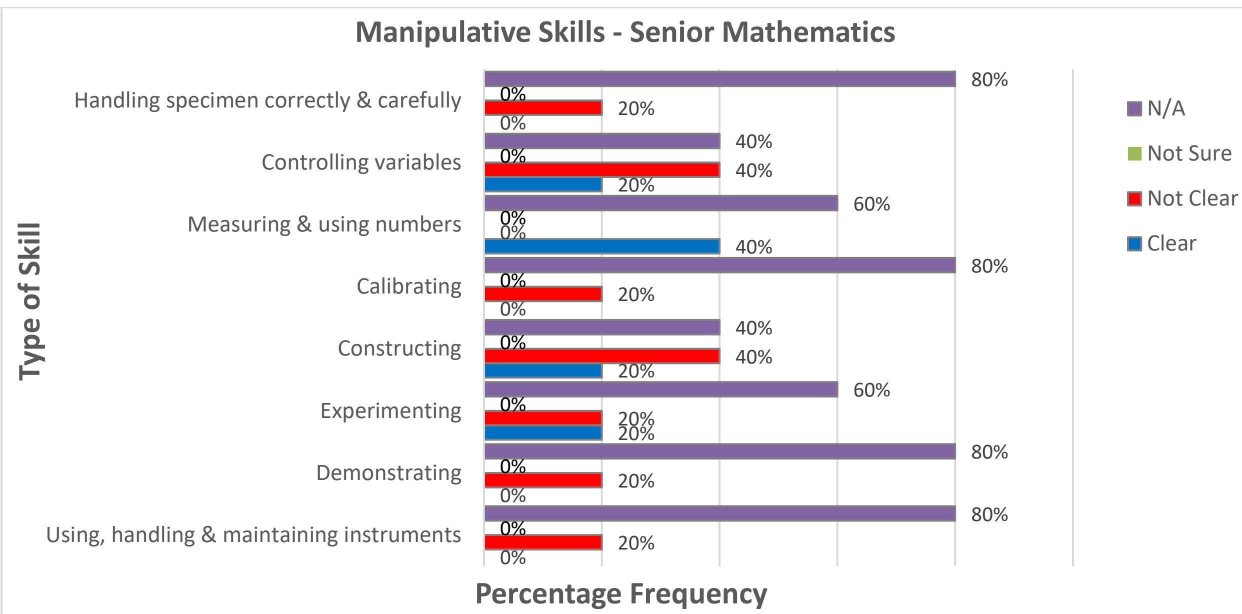


Figure 249: Manipulative Skills - Senior Mathematics

At Junior level, Manipulative Skills in Mathematics lessons observed are shown in Figure 251. The findings revealed that the skills of Demonstrating (83%), Experimenting (67%) and Constructing (67%) were exhibited in the lessons observed. In 50% of the lessons the other skills of Measuring & using numbers and Controlling variables were also observed. The rest of the skills were either lowly observed, not observed or were not applicable.

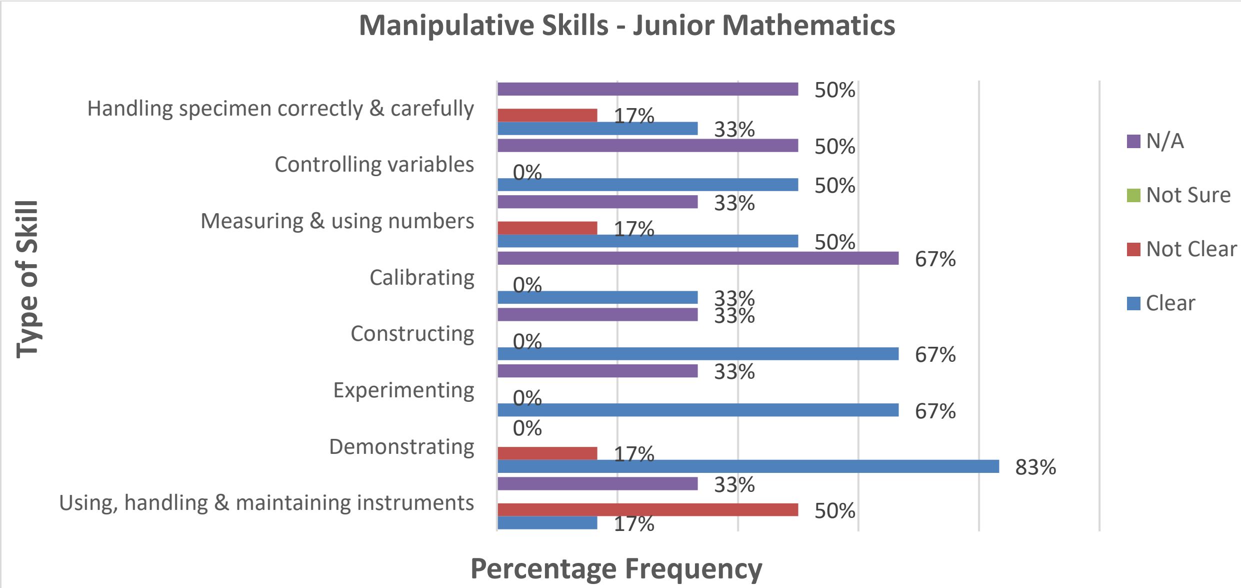


Figure 250: Manipulative Skills - Junior Mathematics

Manipulative skills suffered a setback at both Senior and Junior levels probably due to a number of factors, among them; teaching and learning materials, learner and teacher factors. With regards to teaching learning materials, the knowledge that the Curriculum stipulates would influence the kind of materials the teacher should either put together or advise learners to look for and use. However, the findings suggested that the knowledge aspect for both Senior and Junior levels in some lessons were not in line with the dictates of the STEM Education Curricula for Mathematics. This might have contributed to learners not showing manipulative skills which involve actual contact and use, either in their original state or modified in the course of learning, of the objects as expected. The other reason which might have contributed to learners not showing dexterity could be the preparation for teaching and learning materials for particular lessons. On one hand, at Junior level 17% of the lessons did not indicate the teaching and learning materials to be used and nothing showed what the teachers would use during teaching and learning. On the other hand, 40% of lessons at Senior level had no indication of teaching and learning materials while 20% showed the materials that the teachers would use. Additionally, only 17% at Junior level of the teaching and learning aids were prescribed by the learners out of the lessons which were observed. It could be asserted here that many STEM teachers did not treat the teaching and learning materials with the seriousness they deserved such as the impact on the learning of learners, appropriateness and adequacy hence the low manifestation of manipulative skills in the learners. The learner factor may come in due to the *traditional belief* that the teacher should demonstrate how to do things as learners typically just jolt down points raised by their teachers. Learners may not have been very free to scrutinise the materials before them or look for alternatives to substitute the already provided in order to develop deeper understanding of the concepts under discussion. One such case was that of a Senior lesson at a named Girls Secondary School where the order of fractions were discussed. The girls had the opportunity to use the mathematical instruments such as protractor, compass, rule and pair of scissors but rather opted to use sketches which ended up distorting the portions of segmented sections just like the misrepresentation of the teacher's chart. Had they used the mentioned tools the level of interactions with the materials and therefore manipulative skills could have indicated otherwise and learning would have been more practical and enjoyable. This relates closely to the teachers' inability to free up the learners to other possibilities beyond what they themselves may have provided as teaching learning materials for a particular lesson. Furthermore, teachers might have feared the consequences of allowing learners to use their initiative to bring in other materials other than that which the facilitator may have already interacted with during preparation for lessons. The fear may be due to insecurities of how to handle the unfamiliar issues which could arise from the use of brought in materials where the teacher might have little or no knowledge about. The result could be limiting learners to the teachers' familiar materials so that he or she operates in his or her comfort zones even if that means learners having little or no opportunity at all to interact with such materials to enhance their learning. These results justify the need to have Mathematics practicals as part of assessment in STEM Education.

e) *Communicative Skills*

The results of the Communicative Skills observed in Senior Mathematics lessons are shown in Figure 252. The results indicate that all the Communicative Skills were remarkably observed in the lessons except for the skill of Graphing which was displayed in only 20% of the lessons.

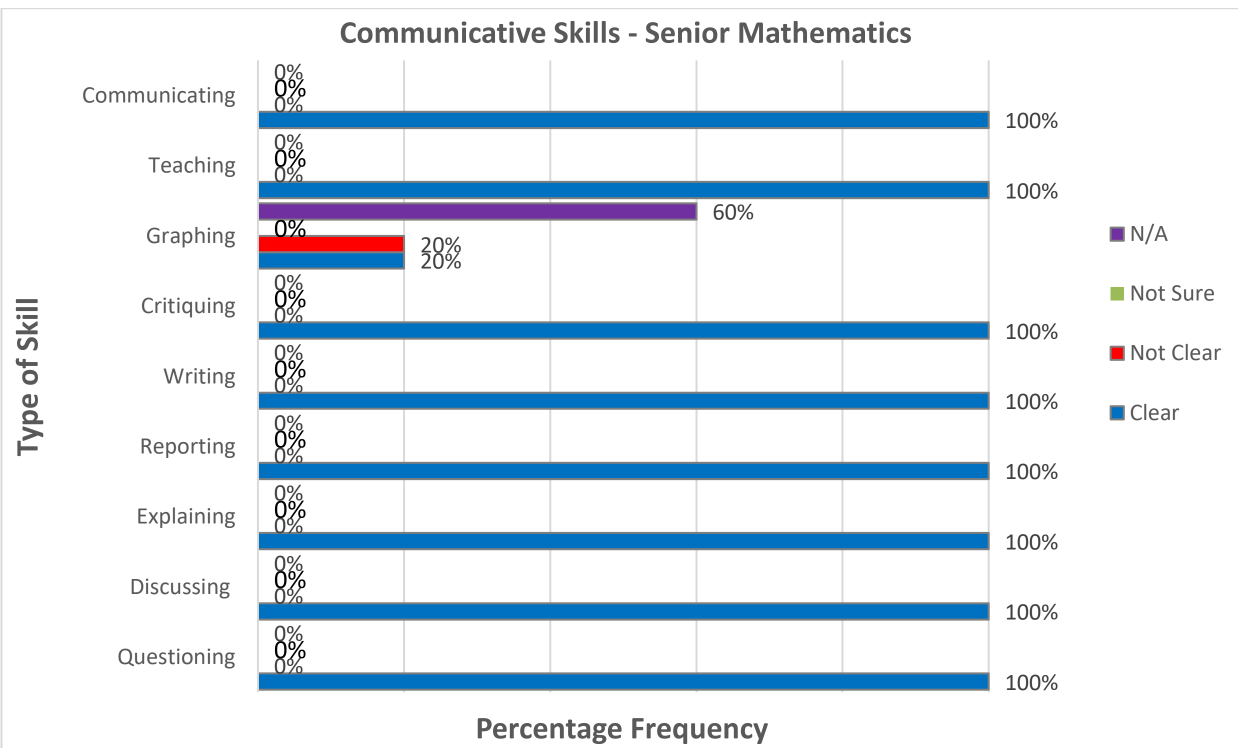


Figure 251: Communicative Skills - Senior Mathematics

Figure 253 shows results of the Communicative Skills observed in Junior Mathematics lessons. It was observed that the skills of Questioning, Discussing, Explaining, Reporting, Writing, Teaching and Communicating were clearly exhibited in all the lessons while the Critiquing skill was demonstrated in 83% of the lessons. The skill of Graphing was completely absent in all the lessons.

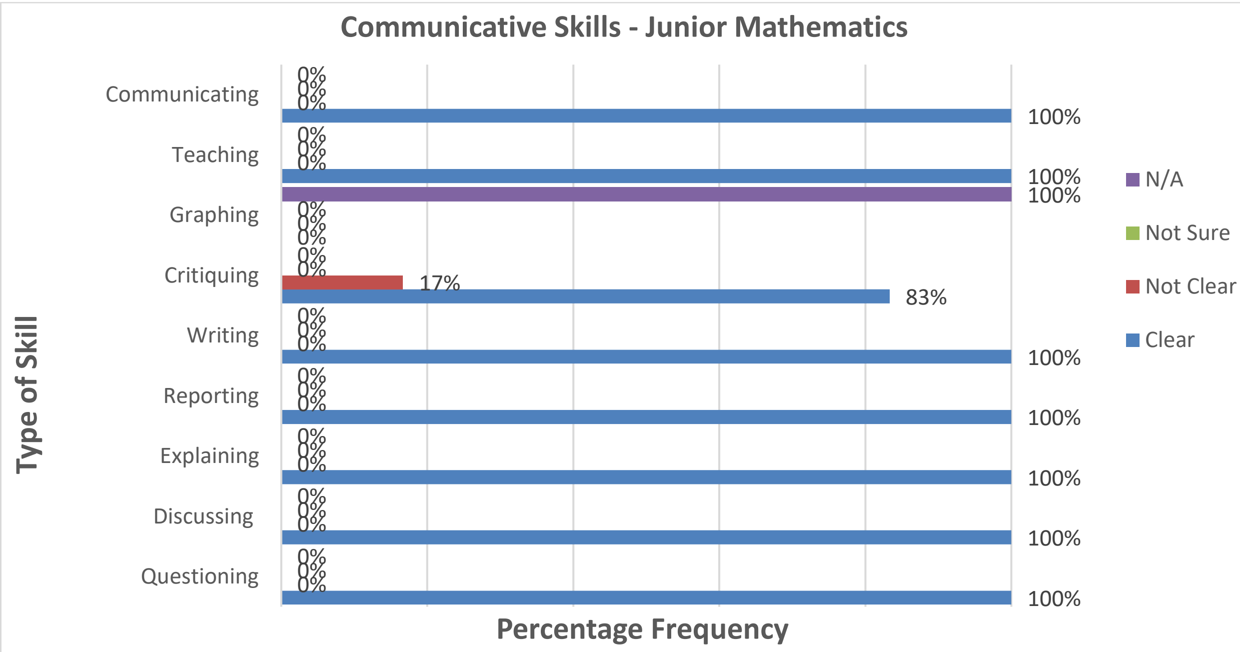


Figure 252: Communicative Skills - Junior Mathematics

From the point of view of understanding the Curriculum, its intentions and implementation, with regards to communicative skills, it might be affirmed that learners were given the opportunities to engage one another and, therefore, be able to express themselves freely through discussions, questioning, writing and explaining. Learners communicated with both their peers and teachers via written presentations which they allowed to be critiqued and, in some instances, prompted defending their standpoints or accepting the inputs from other members' contributions. These observations might have emanated from the teachers' understanding of their roles as facilitators who initiated the learning process and allowed learners to explore thereby owning the knowledge which they created. Considering all the Scientific Skills in Mathematics, Communicative Skills were the most exhibited by the learners at both Senior and Junior levels. However, Graphing was largely considered not to be applicable as shown at 60% and 100% for Senior and Junior.

4.1.15.8. Physics

a) Acquisitive Skills

The results in Figure 254 show Acquisitive Skills for Physics at Junior level for the lessons which were observed during the survey. The findings indicated that out of 9 types of Acquisitive Skills, 2 (Listening and Observing) were clearly displayed, while Searching, Inquiring, Investigating and

Researching were exhibited in 75% of the lessons. Gathering data, Defining operationally and Formulating hypotheses were observed in 50% of the lessons.

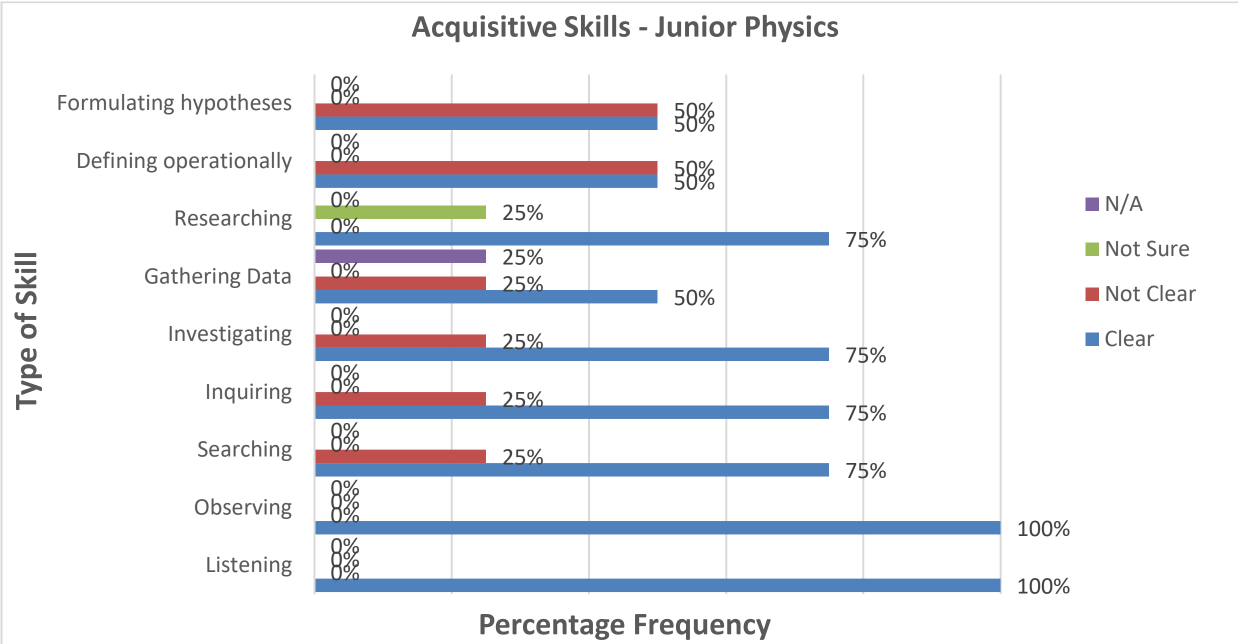


Figure 253: Acquisitive Skills - Junior Physics

At Senior level, all types of Acquisitive Skills in Physics were clearly exhibited in all the lessons observed as shown in Figure 255.

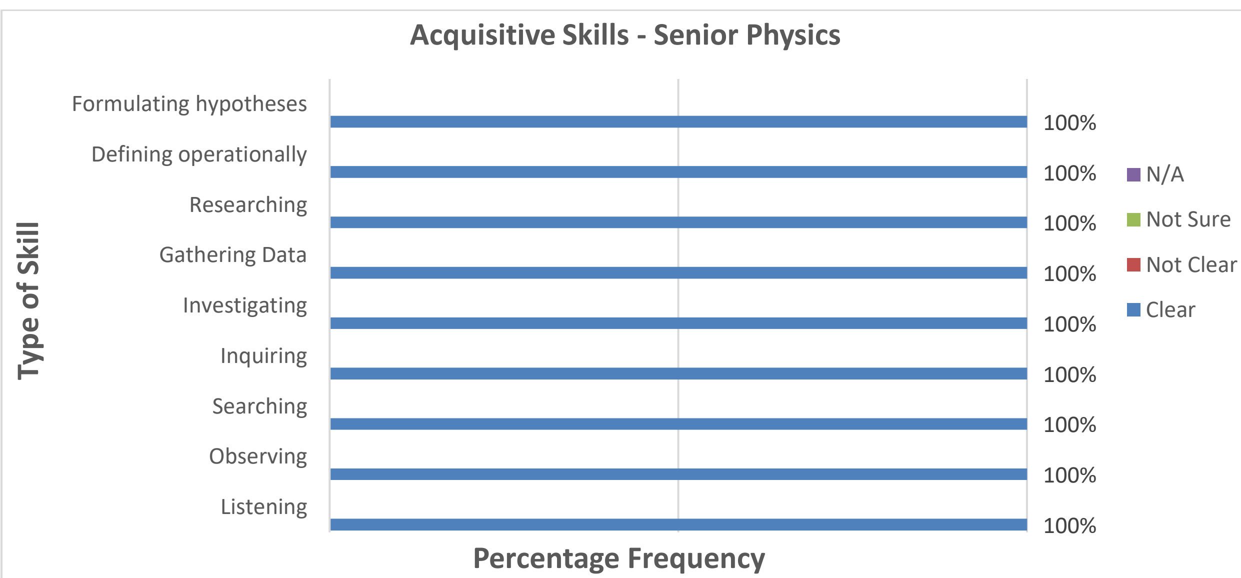


Figure 254: Acquisitive Skills - Senior Physics

As regards to Physics, the learners at both Senior and Junior levels remarkably achieved Acquisitive Skills in conformity with the curriculum intentions. This could have been as a result of teachers having interacted effectively with the curriculum and hence were able to interpret its dictates correctly as they planned and delivered the lessons. This facilitated the attainment of the Acquisitive Skills needed for the 21st Century skills. The implication of this is that the skills that the learners were expected to acquire and develop were suitably planned for and so the lessons were expected to yield the desired outcomes. It entails that learners were given the opportunity to accurately receive and interpret messages, and use five senses to derive characteristics of objects, events and attitudes. They also demonstrated ability to develop active listening, questioning, interviewing and note-taking. However, for the lessons at Junior level where learners failed to demonstrate the skills of Defining operationally and Formulating hypotheses, the reason could stem from the nature of the tasks which might have made it difficult for the learners to exhibit such skills. Therefore, teachers should continuously engage in professional development activities to share knowledge and deepen their understanding of curriculum intentions as well as develop strategies for enhancing skills development in learners.

b) Organizational Skills

Figure 256 shows results on Organisational Skills which were considered in Junior Physics lessons during the survey. The findings indicated that the skill of recording was clearly exhibited in all the lessons and the other 6 types of skills were observed in 75% of the lessons while the skills of Evaluating, Predicting and Inferring were displayed in 50% of the lessons. The skill of outlining was exhibited in 25% of the lessons observed.

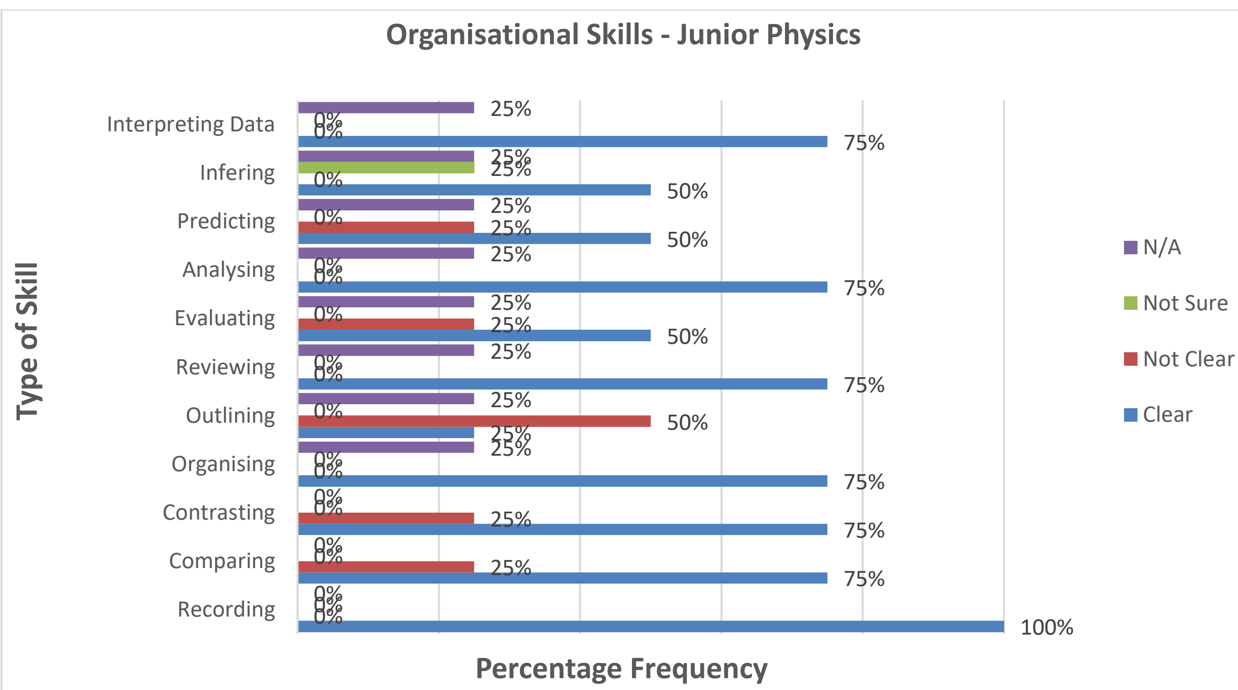


Figure 255: Organisational Skills - Junior Physics

At Senior level, all the 11 types of Organisational Skills were clearly observed in all the Physics lessons as shown in Figure 257.

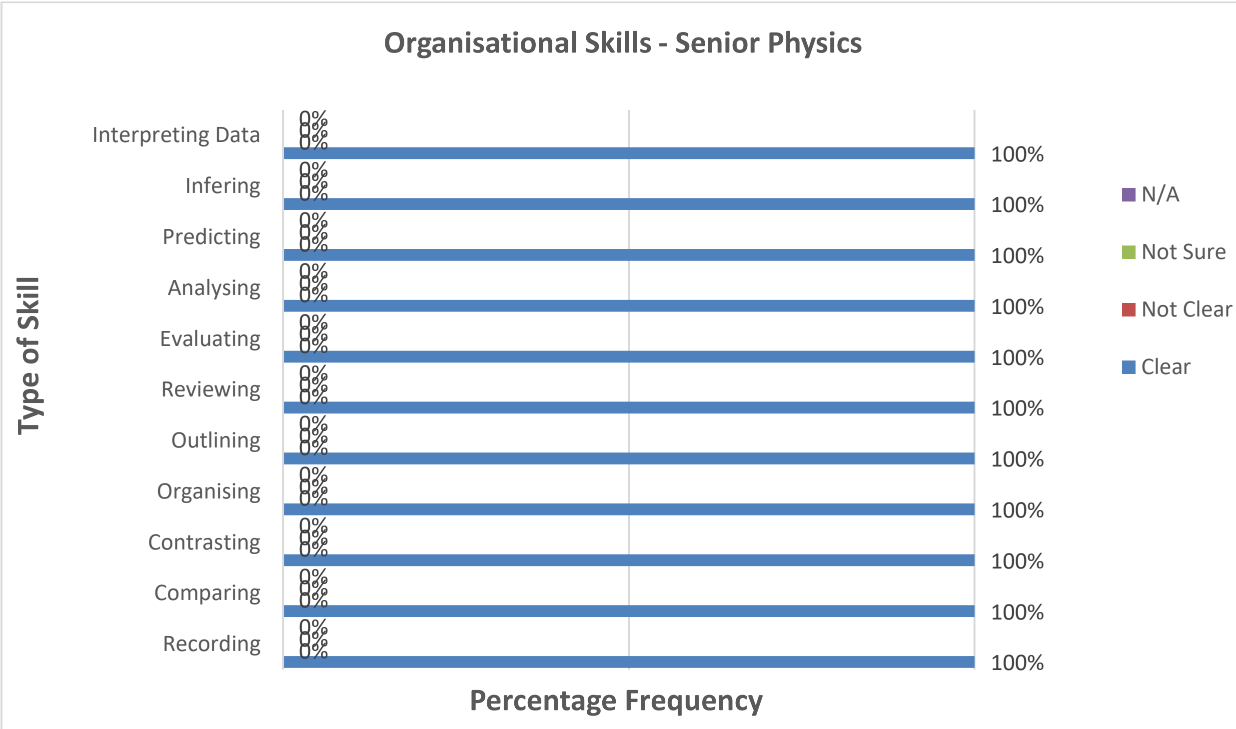


Figure 256: Organisational Skills - Senior Physics

The results revealed remarkable achievement by learners, especially at Senior level, where all the Organizational Skills were clearly demonstrated in all the lessons observed. This might be as a result of teachers being familiar with the STEM Curriculum and that the understood the intensions therein. This implies that the teachers were able to plan adequately and delivered the lessons effectively. The learners, consequently, comprehended the tasks and carried out the activities, leading to the demonstration of the expected skills in this category. However, there were still some lessons at Junior level where learners found it difficult to exhibit some skills such as Outlining, Predicating and Inferring. Teachers should therefore, find ways of fostering the development of these skills through provision of appropriate tasks. They should also promote the spirit of knowledge sharing through collaborative activities such as SBCPD and stakeholder workshops where best practices can be shared.

c) Creative Skills

The results on Creative Skills for the lessons observed at Junior level are shown in Figure 258. The finding indicated that out of the 6 Creative Skills, the skill of Designing was observed in 75% of the lessons monitored during the survey while the skill of Planning ahead was exhibited in 50% of the lessons. The remaining skills were displayed in 25% of the lessons.

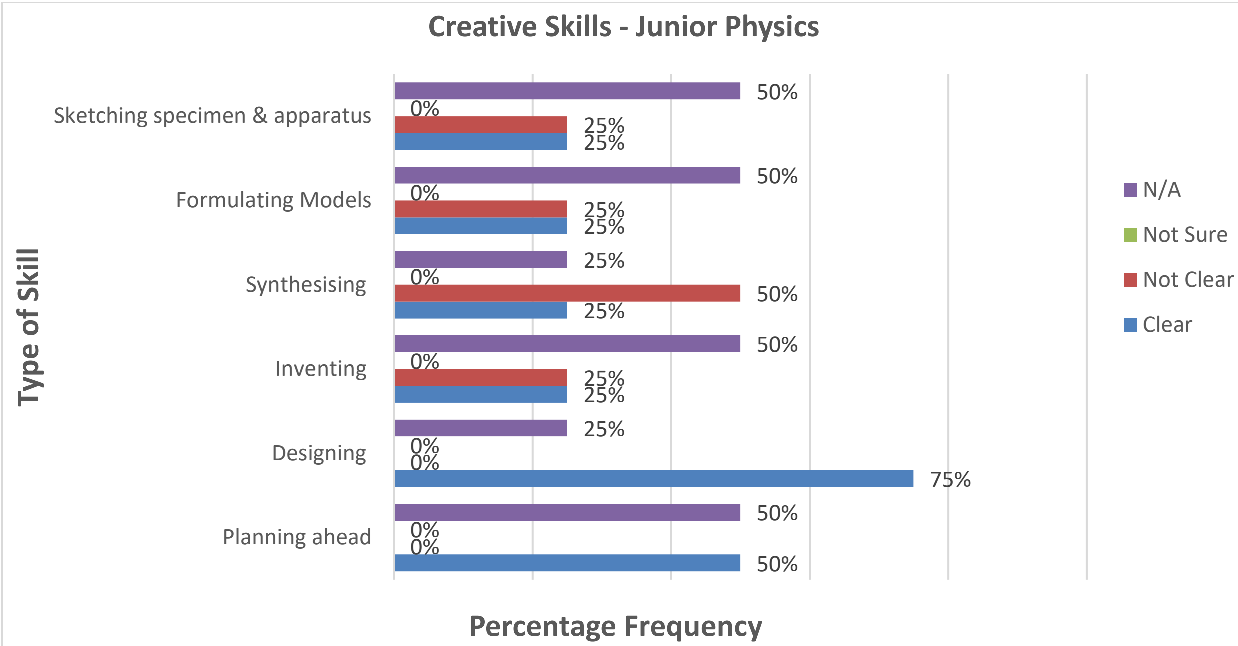


Figure 257: Creative Skills - Junior Physics

At Senior level, out of 6 types of Creative Skills 3 of them (Planning ahead, Designing and Formulating models) were clearly displayed in all the Physics lessons observed while 2 of them were not applicable. Further, it was difficult to indicate whether the skill of Synthesising was applicable in any of the lessons observed. This is shown in Figure 259.

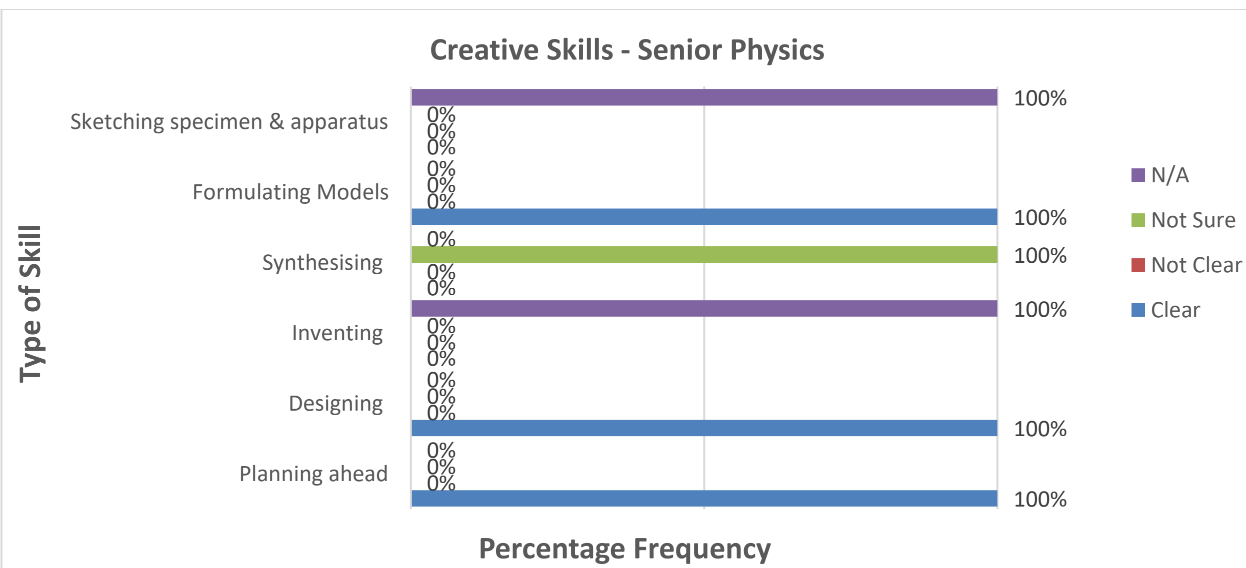


Figure 258: Creative Skills - Senior Physics

The results show gloomy display of Creative Skills in Physics lessons at both Junior and Senior levels. As stated above, Creative Skills interpret the learners' acquisition of knowledge, skills and values required for the future generation. Therefore, teachers should strive to ensure that learners acquire these skills. The low performance by learners could be due to the fact that appropriate tasks which could elicit Creative Skills were not prepared and therefore, learners could not demonstrate ability to create mental or physical models of a process or event. They were also unable to create or figure out a way to do something. The implication of this is that the learners would find it difficult to develop visual recall, rendering, novel visualisation of specimen or find alternatives to accomplish the given tasks. These attributes are also required in research work for the learners to come up with novel products. Teachers are, therefore, encouraged to continuously engage in professional development activities in order to have an in-depth understanding of curriculum aspects and explore various ways of implementing the curriculum so as to positively impact on learners' achievement.

d) Manipulative Skills

Figure 260 shows results in Manipulative Skills in Physics at Junior level. The findings indicated that the skills of Demonstrating, Measuring & using numbers and Controlling variables were exhibited in 75% of the lessons monitored and the skills of Using, handling & maintaining instruments, Experimenting, Constructing and handling specimen correctly were observed in 50% of the lessons. The skill of Calibrating was observed in 25% of the lessons.

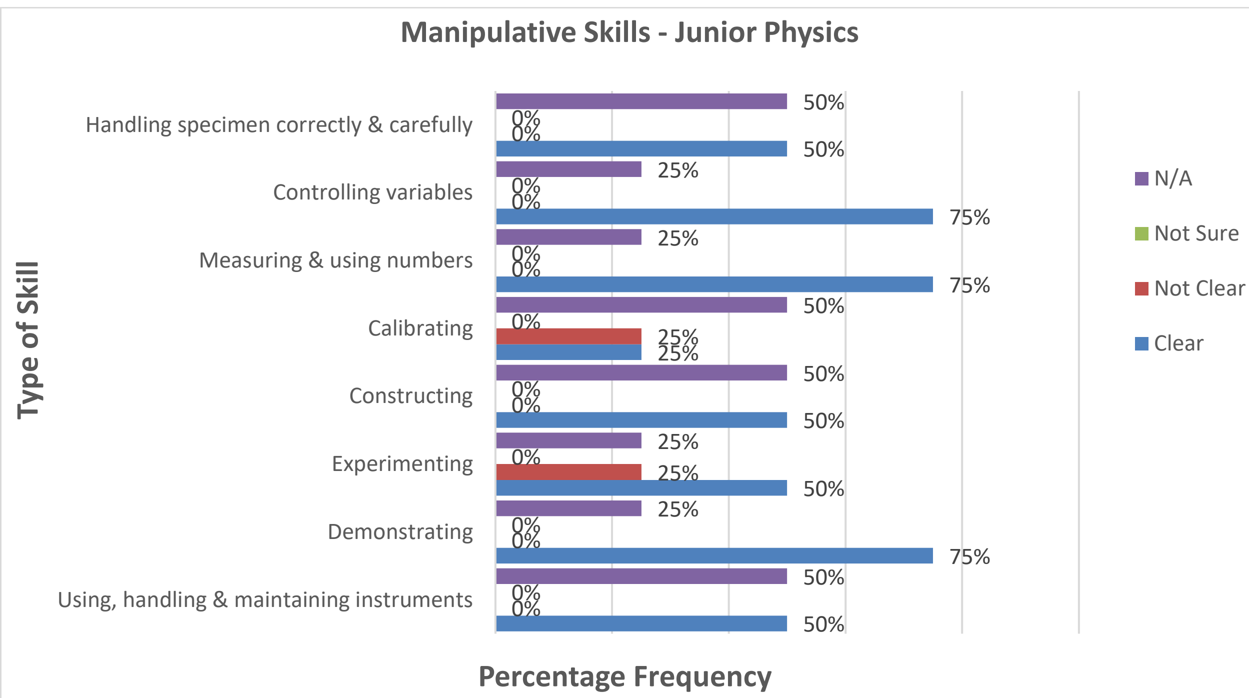


Figure 259: Manipulative Skills - Junior Physics

At Senior level, all the Manipulative Skills in Physics were clearly observed in all the lessons which were monitored during the survey as shown in Figure 261.

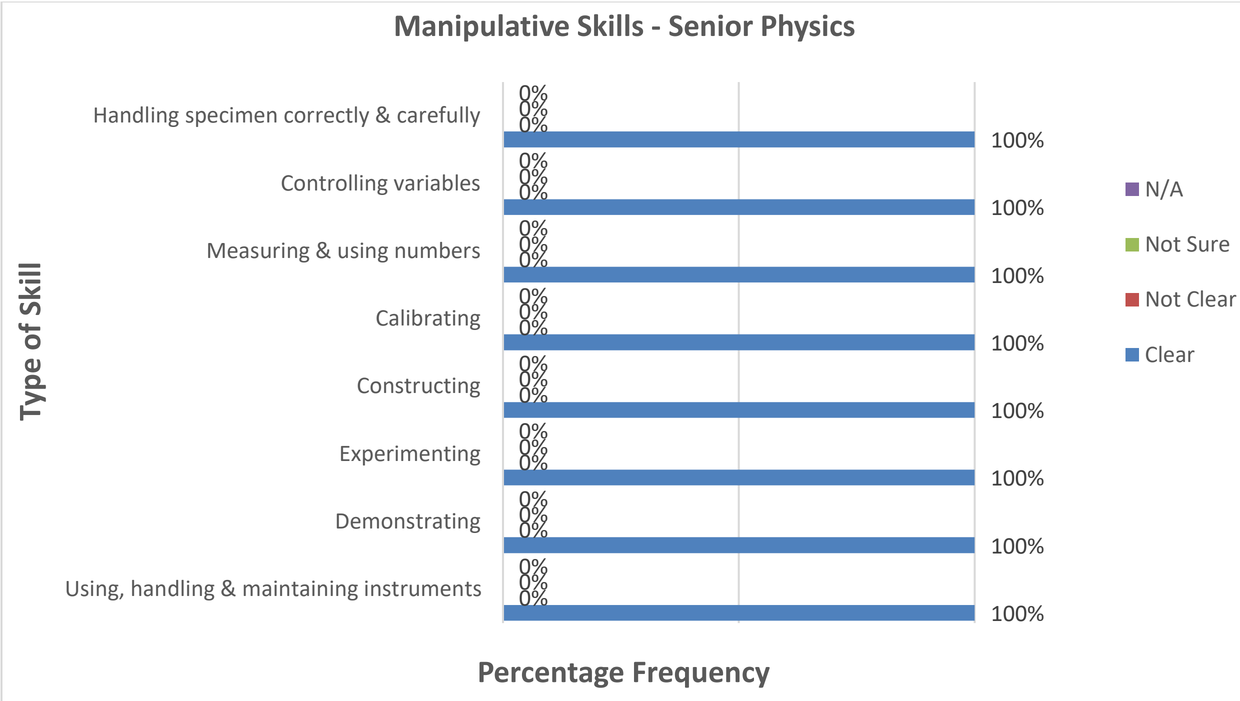


Figure 260: Manipulative Skills - Senior Physics

As regards to Physics, there was outstanding achievement of manipulative skills demonstrated by learners especially at Senior level. The reasons for this may not only be because of the nature of the subject which allows for handling as well as use of apparatus and equipment but also might have been as result of teachers planning collaboratively and hence were able to understand and interpret the STEM Curriculum dictates correctly. The meaning of this is that the planned and delivered lessons were effective to allow learners to exhibit Manipulative Skills such as Demonstration, Controlling variables, Measuring and using numbers. However, there were still some lessons at Junior level where learners found it difficult to display some skills such as Using, handling and maintaining instruments, Constructing, Calibrating and Handling specimen correctly and carefully. This would mean that learners were deprived of physical interactions with materials to help in understanding of underlying principles in the concepts they were learning. Teachers to continuously engage in professional development activities so as to positively impact on learners' achievement and also allow teachers to have an in-depth understanding of curriculum aspects and explore various ways of implementing the curriculum.

e) Communicative Skills

Figure 262 shows results on Communicative Skills in Physics at Junior level which were obtained from the lessons observed during the survey. The findings revealed that 7 types of skills out of 9 were clearly exhibited in all the lessons and the skill of Critiquing was observed in 75% of the lessons while the skill of Graphing was not observed.

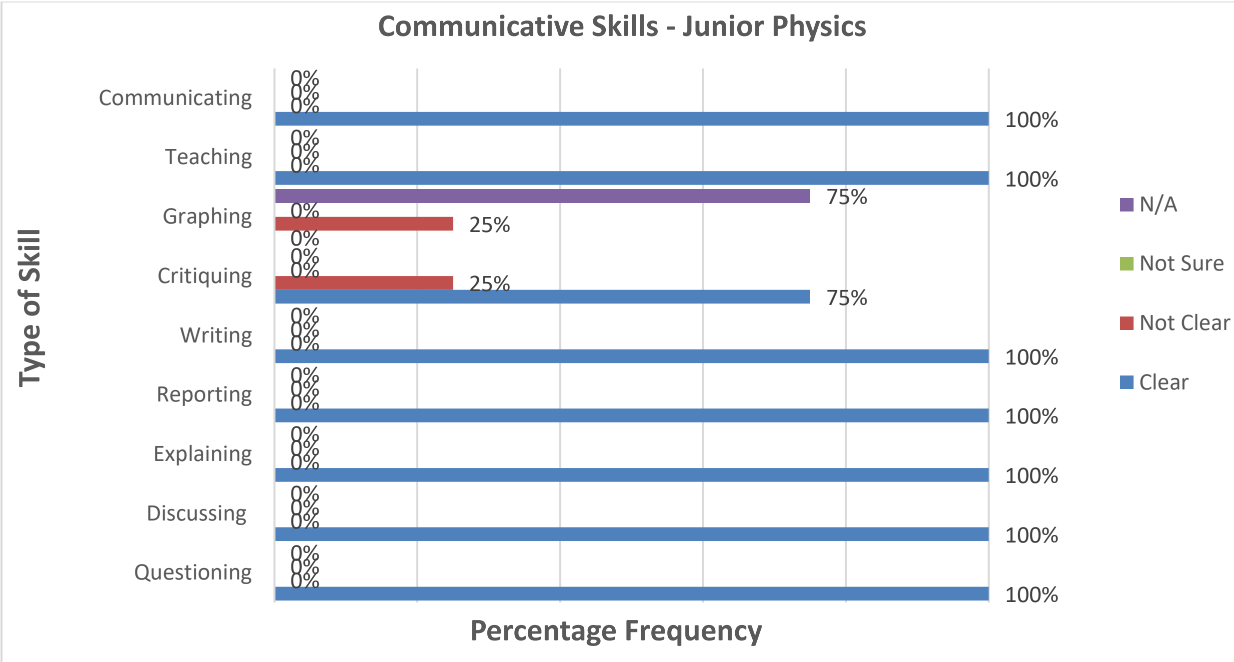


Figure 261: Communicative Skills - Junior Physics

At Senior level, all Communicative Skills, except for the skill of Graphing, were clearly observed in all the lessons monitored as shown in Figure 263.

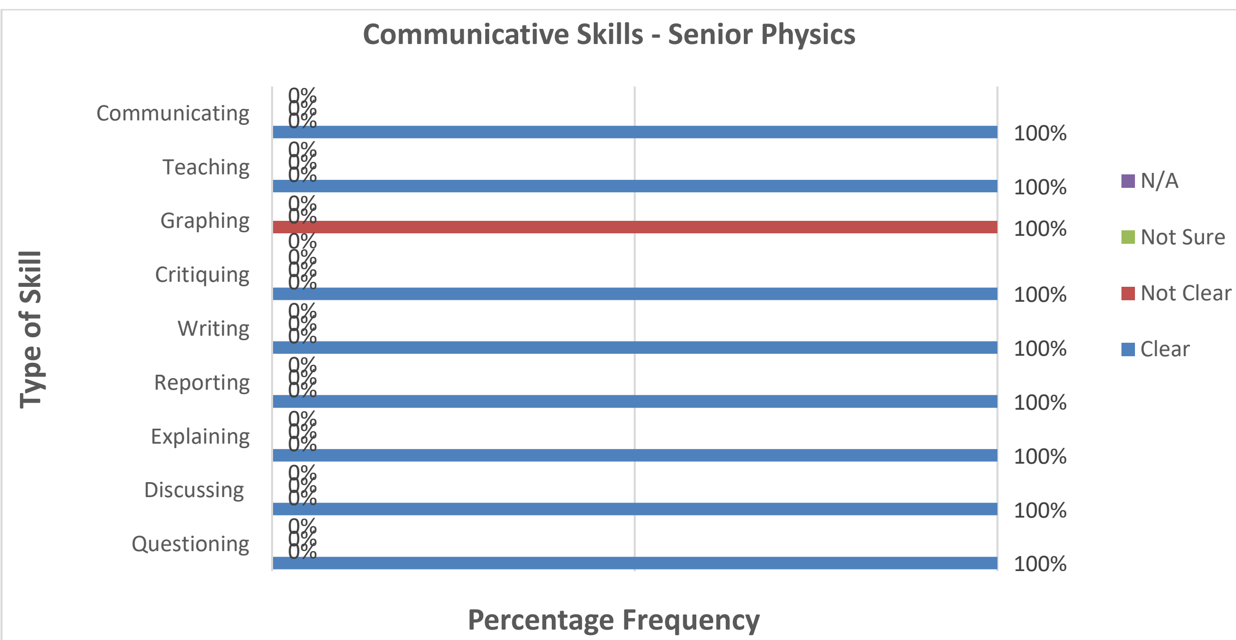


Figure 262: Communicative Skills - Senior Physics

The results indicated that there was noteworthy achievement in communicative skills at both Senior and Junior levels. This could have been that the learners were given chance to express themselves freely through discussions, questioning, explaining and writing. Learners communicated with both their peers and teachers through presentations and further contribution from the entire class. This facilitated the demonstration of the acquired Communicative Skills such as Questioning, Explaining and Discussing. However, the skill of Graphing was a challenge to the learners at both Junior and Senior levels. This meant that learners were deprived of the opportunities to construct, analyse and interpret graphical information. The implication of this is that the learners become functionally illiterate hindering their STEM competence development. There is need, therefore, for teachers continuously engage in professional development activities so as to positively impact on learners' Communicative Skills attainment on one hand. On the other hand, allow teachers to have a thorough understanding of curriculum aspects and search for various ways, including training opportunities, of ensuring that the curriculum is well implemented.

4.1.15.9. Summary of Scientific Skills

Figure 264 shows results of overall Scientific Skills in the lessons observed across all the STEM subjects. The findings indicated that there was above average demonstration of Acquisitive Skills (66%), Organizational Skills (64%) and Communicative Skills (83%) in all the lessons. However, the skills of Creative and Manipulative were observed in only 25% and 32% of the lessons respectively.

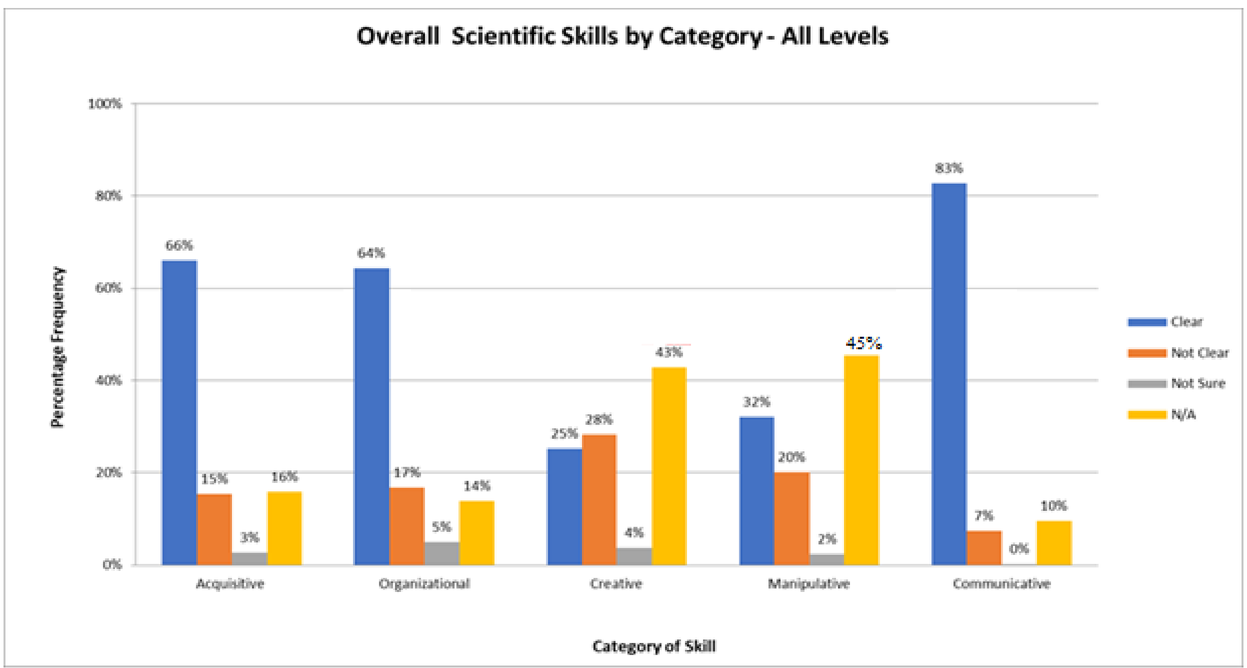


Figure 263: Summary of Scientific Skills

The prominent demonstration of acquisitive, organizational and communicative skills are evidence enough that it might have been easier for teachers to plan and deliver lessons with activities that elicited these skills. However, it is not clear what was being organized and communicated because the Creative and Manipulative Skills, which are the main drivers of STEM Innovation, were lowly exhibited in most of the lessons observed in all the STEM subjects. The low exhibition of these important skills raises concern as it entails that learners would not be accorded with prospects to think in an imaginative approach, interact with materials and equipment so as to understand underlying principles and further generate novel or unorthodox solutions. The reason for this may have been that teachers had inadequate content knowledge and pedagogical skills and hence were still struggling to plan for activities that could elicit higher order skills such as creative and manipulative.

The indication of not applicable rating in all the skills especially in the skills of Creative and Manipulative is equally a source of concern as it may suggest that the understanding of these skills might have been a challenge to the teachers as well as the observers. The implication of this is that interventions may be misdirected as the presented data may not be adequately reliable. In this regard, tailor made capacity building programmes which include focus on the "way of seeing" in the teaching and learning process should be strengthened at all levels of STEM Education delivery.

4.1.16. Research Work

In the context of STEM Education in Zambia, research is a sandwich intermediate process in which the theories in STEM Education are transited into evidence-based products closer to prototype status as the learners go through the learning process. Research informs action, proves theories, and contributes to the development of knowledge. In order to ensure that there is sustainable development, research is vital because it helps to anticipate future challenges and identify current problems so as to provide possible alternatives and solutions. Through research learners are expected to develop in-depth understanding of concepts in the subject areas they are pursuing so that they add value to the economic developmental prospects of any society. Learners should do research on any topic of their choice within the framework of the Curriculum pathway that one is pursuing. The rationale for undertaking research in STEM Education is to foster systematic investigation into material, situations and processes in order to establish the facts and reach conclusions about challenges or problems being faced in different aspects of life. Research work has been divided into two specifics; minor and major. Minor research, which is a major assignment, entails short investigations in any subject that a learner is taking in the Curriculum and contributes towards the 65% grade marks of the School-Based Assessment (SBA). The detailed explanation regarding minor research is found under continuous assessment as major assignment (See Figure 9). The major research which will be treated as a separate activity involves prolonged studies for two years at junior level and three years at senior level. The research topic may be based on any STEM field of study in a particular Curriculum pathway which will integrate STEM subjects. The overall mark for the major research is 100% and will be reflected separately on the certificate. A learner is expected to go through a process of research which will involve three main aspects namely: research report, research defence and research product as explained below.

4.1.16.1. Research Report in STEM Education

A research report is either a document that contains basic aspects of the research project or record of data that is prepared after analysing gathered information. It can also be considered as a condensed form or brief description of research work presented. In STEM Education, the assessment of the research report will carry 30% of the 100% allocated for research. The sequential logical flow will comprise the following aspects: Title, Abstract, Introduction/Background, Problem Statement, Objectives/Research Questions, Literature Review, Methodology, Results/Findings, Conclusion, Recommendations and References. Additionally, formatting of the research report will have font type of Times New Roman, font size 12 points and line spacing of 1.5.

4.1.16.2. Defence in STEM Education Research

In STEM Education, apart from a report and product, a learner will be required to carry out an oral presentation of the research in form of a defence. A research defence is a viva voce presentation of evidence of a research report before a chosen committee or audience. The main purpose is for defender to present the research work so that the committee validates it. Additionally, the defender receives input for further consideration and improvement if any. The assessment of the research defence will carry 30% of the 100% allocated for research (See Table 3). The Aspects that will be assessed during the defence are:

(i) Assertiveness: Confidence, Self Esteem, Gestures, (Rapport with audience)
(ii) Understanding of Subject matter (Communicating most important points of research work, ability to respond to questions raised)
(iii) Quality of power point presentation (Coherent Power point form, Logical Flow)
(iv) Time Management (Time bound (Should specify Presentation and Question Time)

4.1.16.3. Product in STEM Education Research

A product in STEM Education is a research invention, innovation, artefact or manufactured good that emanates from a research process. The assessment of the research product will carry 40% of the 100% allocated for research. The aspects that will be assessed on the product are:

(i) Research work involved that will include originality, innovativeness, use of appropriate materials (preferably largely local), value addition principle,
(ii) Practical use to ascertain the operational, application in reality, environmentally friendly, quality, and cost effective of the product,
(iii) Operational principle will assess how well Scientific, Technological, Engineering and Mathematical principle (s) are applied and illustrated, how user friendly the product is, and whether it can easily be replicable and scalable, and
(iv) Suitability for commercialization of the product will assess the potential of the product for market entry, patentability and whether it could be able to solve the societal problems.

In this research, the focus was to ascertain whether the minor and major research works had commenced in the STEM schools. Figure 265 indicates the findings on whether research work had commenced or not in schools. It was observed that no school had commenced research work in any of the STEM subjects despite having indicated that they had planned for it.

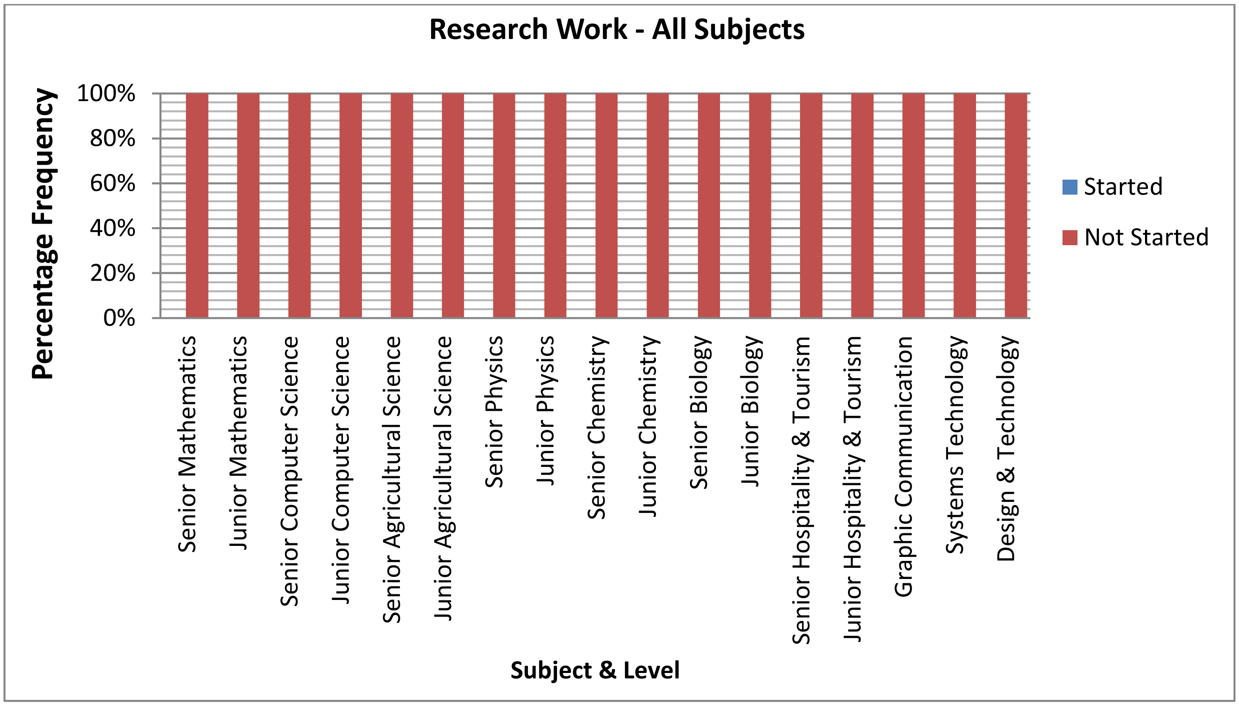


Figure 264: Research Work - All Subjects

From the research work results, there were various reasons put forward for not engaging learners in research at the time the survey was conducted. One such reason was that the STEM School started operating two weeks after the rest of the school calendar had begun, resulting in both teachers and learners not having done much teaching and learning respectively to engage in research work. The other reason was that some teachers did not fully understand how to go about the research work hence they were unable to guide learners in carrying out research work. The implication of this is that there might be more work to be done by both teachers and leaners to offset the backlog. It is recommended that teachers be capacity-built in research skills and that they should carry out research and publish their works in the Zambia Journal of Teacher Professional Growth (ZJTGP) and Zambia Educational Journal for Science, Technology, Engineering and Mathematics (ZEJSTEM) in order to up skill their capacity in research work.

4.1.17. School-Based Assessment

In the context of STEM Education, Continuous Assessment is the frequent evaluation of learners' learning performance and progress through out a prescribed course of study as distinct from summative examination. Learners will be assessed using assignments, practicals, tests, and workbook management. The 65% Continuous Assessment will comprise of School-Based

Continuous Assessment (SBCA). The 65% will be distributed as follows: Assignments 30%, Practicals 20%, Tests 10% and Workbook management 5%.

The illustration of the details of the components of SBCA conceptual framework is shown in Figure 6.

4.1.17.1. Tests

A test is a written task intended to measure a learner's knowledge and skills. In STEM Education, learners may be required to write tests as hardcopy or softcopy. Further, some electronic tests will require to be answered and submitted in real time. The tests will carry 10% of the 65% allocated for CA. Learners will be required to undertake two tests per Term; namely Mid-Term and End Term respectively. There will be no tests in Term 3 of Grade 9 and Term 3 of Grade 12. At junior level the total number of tests will be 10 while at senior level the total number of tests will be 16. At the end of the level (junior or senior) the aggregate will be found by dividing the total marks obtained by the number of tests written (See Figure 7).

4.1.17.2. Practicals

Practicals are assessment tasks which involve learners working in groups or individually as they observe or manipulate objects to build up understanding of concepts through collection, processing and interpreting data. In STEM Education, the number of practicals learners will be required to undertake per Term will be dependent on the specific subject areas. Each practical will carry 20% marks. The aggregate will be found by dividing the total marks obtained by the number of practicals undertaken at the end of junior or senior course. The details and tabulations are shown in Figure 8.

4.1.17.3. Assignments

Assignments are tasks given to learners to be done outside class time on content already done or yet to be done. Assignments are intended to enhance learners' learning capabilities. Therefore, learners will be required to do one assignment per Term at both junior and senior levels. There will be no assignment in Term 3 of Grade 9 and Term 3 of Grade 12. The total number of assignments will be 5 and 8 at junior and senior levels respectively. Each assignment will carry 10% marks except for the research-based major assignment which will carry 20%. At the end of the level (junior or senior) the aggregate will be found by dividing the total marks obtained by the number of assignments given. Details are indicated in Figure 9. The research-based major assignment will be in form of a research as explained under research report above.

4.1.17.4. Workbook

In the context of STEM Education in Zambia, a Workbook shall be referred to as a learner repository platform in either soft or hard copy format. Learners will document their learning activities and experiences validated by the teacher in the process of teaching and learning with the view of attaining CCAT learner status. Learners' workbooks will be assessed once at the end of each Term. At junior level the workbooks will be assessed 6 times while at senior level the workbooks will be assessed 9 times. The total aggregate score for workbook assessment will be 5% and each workbook's Termly assessment will carry 5%. The 5% will be allocated from the following aspects; General management, Practicals, Assignments, Tests, Daily reflections and Research activities. See Table 1 for weight allocation.

Figure 266 shows results for assessment in all the fifteen STEM secondary schools in the subjects offered. The findings revealed that no records on school-based continuous assessment were found in any of the subjects monitored. Various reasons were given as to why the learners were not subjected to the demands of the Transitional STEM Education Curriculum as outlined in the syllabi.

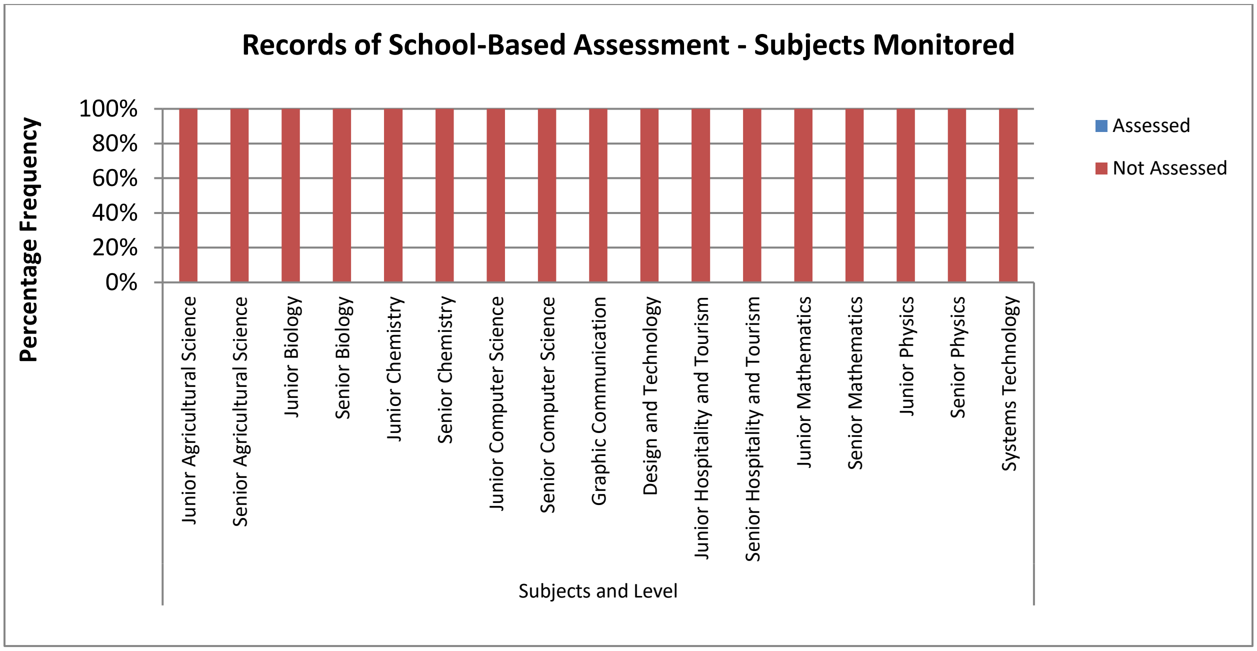


Figure 265: Records of School-Based Assessment - All Subjects

The record of results on school-based continuous assessment is a source of serious concern in STEM Education because it may affect the scheduled teaching and learning activities due to work backlog. The reasons for SBCA not being done might be inadequate time between the commencement of STEM Curricula implementation and the monitoring survey exercise. The other reason was the insistence by some school administrators that all learners in their schools were supposed to follow the usual assessment criteria regardless of the differences in 2013 and 2019 Curricula. It should be noted that two types of curricula were simultaneously being implemented in the schools. As the 2019 Transitional STEM Education Curriculum was phasing in, the 2013 curriculum was being phased out for Grades 8 and 10. The dual implementation of the curricula led to non-adherence to the stipulations outlined in the 2019 Transitional STEM Education Curriculum for fear of antagonizing the authority within the school setting. Additionally, it was established that some schools which are undergoing phasing in and phasing out did administer assessment tasks in line with non-STEM operational conditions. Further, some school administrators together, with the teachers may not have read the assessment criteria sections of the Curriculum in order to understand how it should be done resulting in not having learners assessed as guided within the documents sent to the schools. The implications of the findings would be that there would be more compressed work in the second Term as work for the previous Term would need to be catered for as well. It is, therefore, recommended that STEM schools administrators be guided further in order to strengthen their skills in the management of SBCA for effective implementation of both the 2013 and 2019 Curricula.

4.1.18. Workbook Utilization

In the context of STEM Education in Zambia, a Workbook shall be referred to as a learner repository platform in either soft or hard copy format in which learners document their learning. In the context of STEM Education in Zambia, a Workbook is a learner repository platform in either soft or hard copy format in which learners document their learning activities and experiences validated by the teacher in the process of teaching and learning with the view of attaining Critical Creative and Analytical (CCAT) thinking learner status. The bias of the Workbook will be in line with the constructivist STEM ideals in which the learner takes the centre stage. This means that the Work book activity processes will be triggered by teacher, driven by learner and validated by teacher. The Workbook will be provided and owned by the learner or the institution. The learners are expected to have a record of practicals, assignments, tests, daily reflections and research activities. As such the learner's workbook becomes a major resource for a learner to organize the thoughts and the learning progress in a coherent way for present and future references Workbooks can vary in structure and approaches. This means that the layout may vary according to the lesson concept. Therefore, learners have opportunities to provide diverse multiple viewpoints. The notes in the workbook should be co-developed by learner and teacher. Despite being cumbersome the workbook is an inevitable process as it helps to develop desired learner competencies. In STEM education workbooks will be used to track the progress of learners. To be effective in tracking and assessing learning progress the teachers and learners need to perform specific roles as indicated in chapter 1. The details of Workbook assessment is given under SBCA. Therefore, in the context of this research the Workbook focused on whether learners had a record of practical's, assignments, tests, daily reflections and research activities written and how it was organized. The following are results and analysis on workbook utilization across STEM subjects.

Figure 267 shows results on work book utilization across all STEM subjects observed. The findings disclosed that at junior level Computer Science, Agricultural Science, Chemistry, Hospitality and Tourism while at senior level Mathematics, Physics, Biology, Graphic Communication, Systems Technology, Hospitality and Tourism had learners not yet introduced to the use of work books by their teachers. Conversely, at junior level Mathematics, Physics, Biology as well as at Design and Technology & at senior level Computer Science, Agricultural Science and Chemistry, had indicated use of the work books. However, the degree of usage amongst these subjects was average and below and the extent of usage varied from 17% in Junior Mathematics to 50% in Junior Physics and Junior Biology respectively.

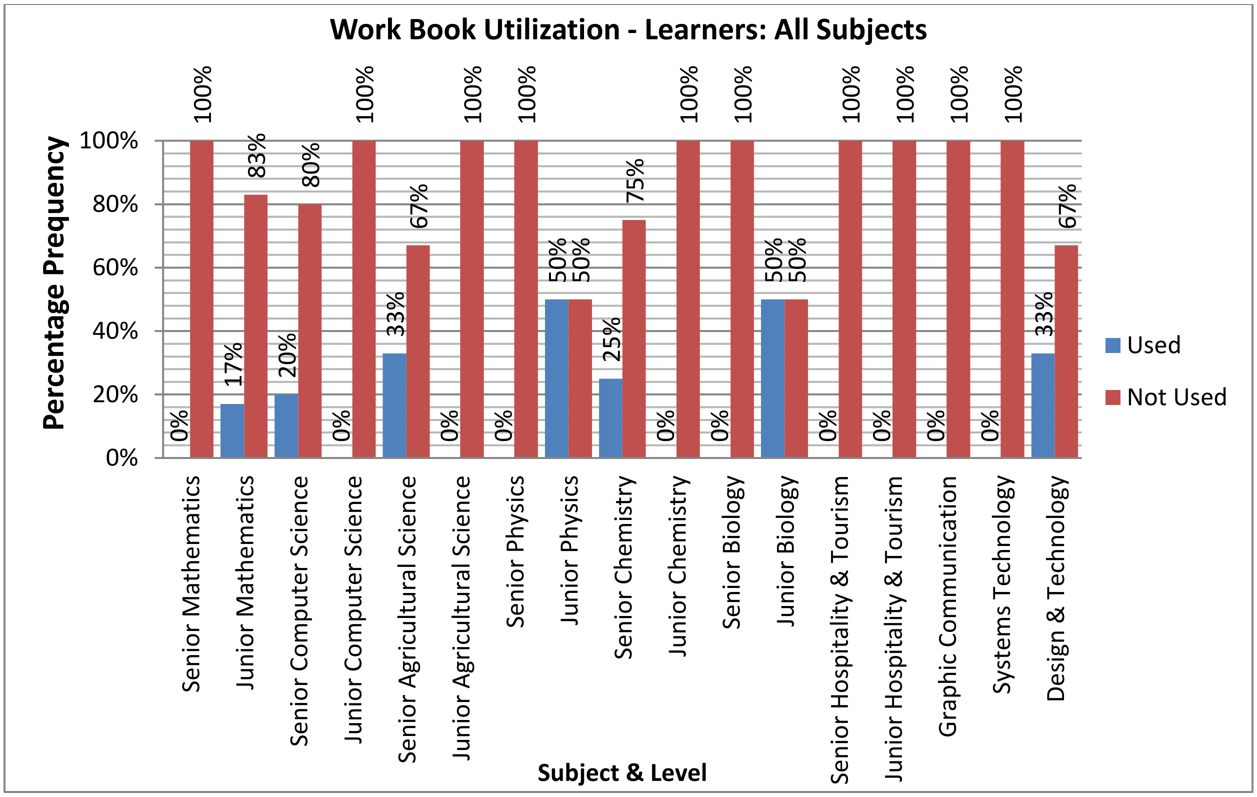


Figure 266: Work Book Utilization - Learners: All Subjects

The revelation from the findings that Workbooks were not fully exploited despite the availability of information in the respective Curricula on their use and constituents entail that there might have been misunderstood by the teachers. This is because the teachers might not be familiar with how the Workbooks should be utilized. The other reason might be that teachers misunderstood the non-giving of notes to mean not having roles as regards to the documentation of information in Workbooks. Additionally, some teachers interviewed stated that amongst the reasons the Workbooks were not being used was that they were actually waiting to receive them from NSC then give to their learners as they were thought of as being special books. Yet another reason why the learners' Workbooks were not being utilized may be emanating from the non-consolidating and summarization of lessons as evidenced during lesson development and conclusion. Nevertheless, for those who used the Workbooks, it was observed that the usage varied within and across subjects and in some cases it was dependant on the teachers' use of the board. Figure… shows variety of learners' workbooks:

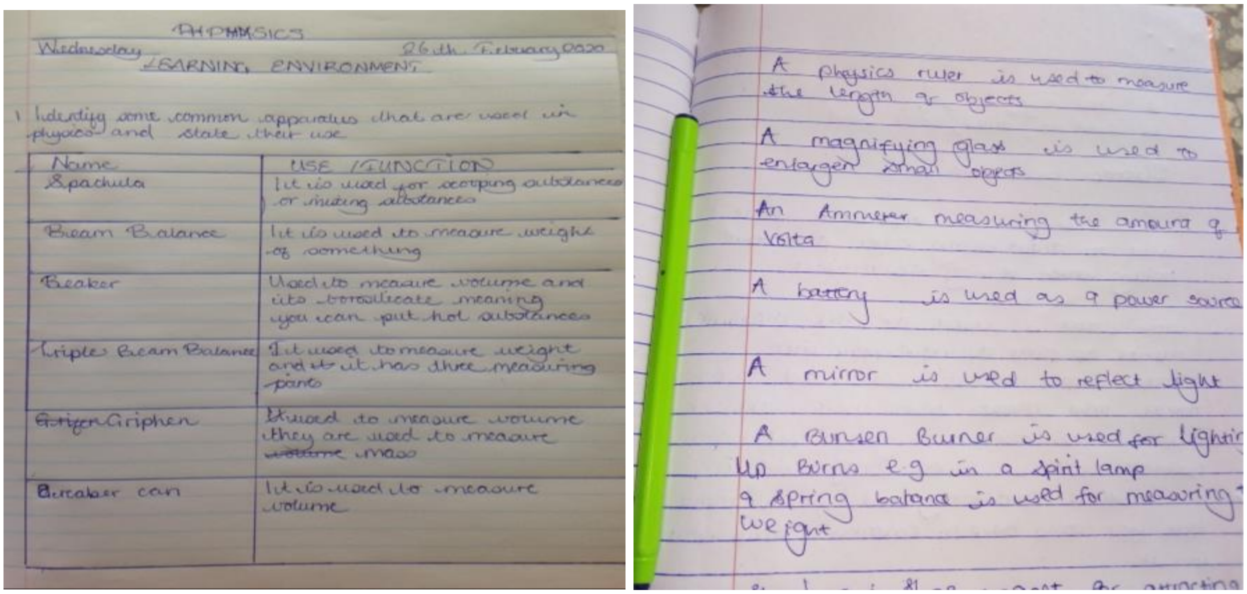


Figure 267: Variety of work in learners Workbooks

The sample extracts in Figure 268 showing variety in style of writing in learners' Workbooks from the same class on a similar topic suggests that learners were able to organize their work the way they conceptualised. This shows that learners can effectively document activities in a variety of approaches. This is encouraged as it makes the learners to develop necessary Scientific Skills. The ability of these learners to capture the main learning points and organize their work in their own systematic manner might be because the lesson was characterized with good board plan usage as shown in Figure 269 below.

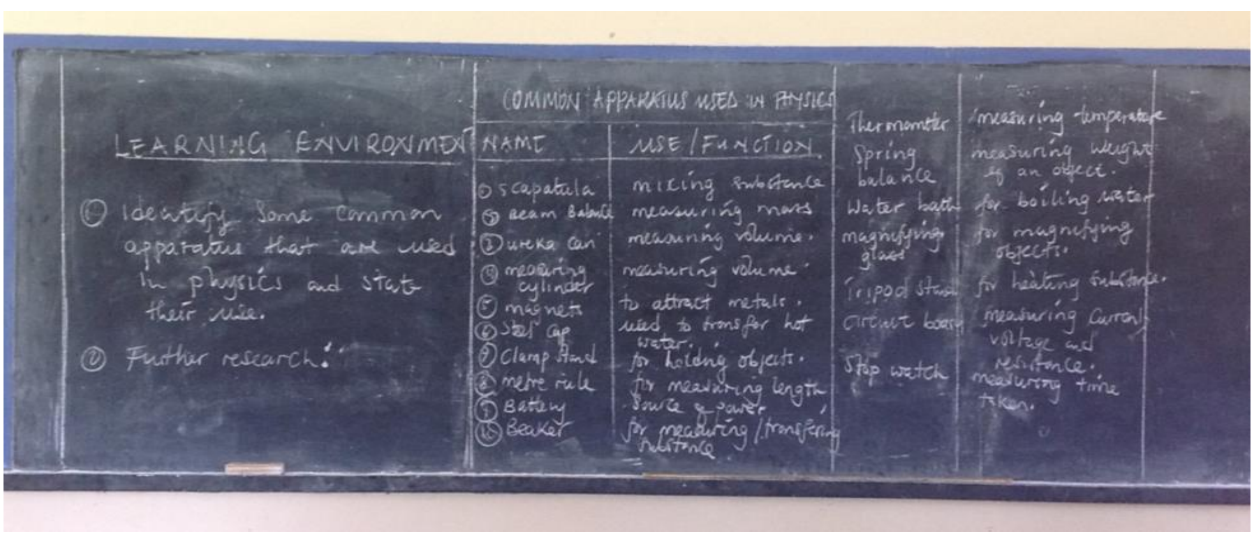


Figure 268: Board plan

The good board plan not only supported the creation of an enabling environment for learners to trace the thought flow effectively but also helped in capturing and documenting lesson learning points in Workbooks in a systematic manner. Other than good board plan, the effective utilization of the Workbook will also be dependent on how the teacher trains learners on its use as well as the facilitation and provision of appropriate tasks. In STEM Education, learners require to be capacity-built on how to record practicals, research, tests, assignments and daily reflections appropriately in the Workbooks. This will serve as evidence of the thought organization of the learner in the learning processes. As such the learner's Workbook becomes a major resource for a learner to organize the thoughts and their learning progress in a coherent way for present and future references. Further, it should be noted that the management of the Workbook is part of the learner's progress in STEM assessment. Conversely, even though most subject teachers claimed, through questionnaire responses, that their learners were using the Workbooks on the contrary the findings during the actual lesson observation revealed that not all the learners recorded the necessary aspects that needed to be recorded as shown in the Figure 270.

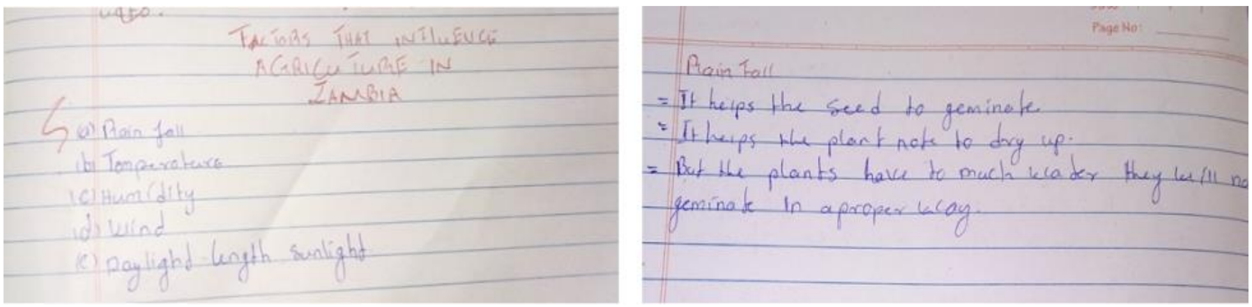


Figure 269: Learners initiative of documentation in work books

As indicated in Figure 270 it can be assumed that learners used their initiative to document in their books. This figure shows how differently learners recorded information in the same lesson. Although one could argue that learners showed creativity, the diverse views, constructivist approaches and organization of the work were not adequately reflected. The scanty information exhibited might mean that the main learning points were not clearly understood by the learner. There is, therefore, need for teachers to trigger what is to be documented in the Workbooks, provide support as well as validate what the learners document. To do this, teachers ought to ensure that an enabling environment for CCAT is created during the learning process. The implications of these findings could be that most learners would probably miss out on important learning points resulting in them being unable to create accurate knowledge about particular subject matter because the point of reference would be lacking thereby relying only on text books or teachers' notes if any. Arising from such scenarios, it might be difficult to trace the challenges and assess progress of learners. Consequently, the STEM Education Curriculum's intentions of tracking continuous learning progress may be hindered. In this regard teachers should facilitate the documentation of all practicals, assignments, tests and research work in Workbooks. In order to attain this, there is need for teachers in all STEM subjects to include Workbook management aspects as they engage in CPD activities at all levels.

Conclusion

This research endeavoured to assess the STEM Education implementation in the 15 STEM Secondary schools following the commencement of the 2019 Transitional STEM Education in Zambia. To achieve this, the following objectives drove the research survey:

a) To determine the existing status of the STEM Schools in terms of general school information
b) To assess teachers understanding of STEM Education Curriculum intentions and implementation
c) To evaluate how the STEM Education Curriculum is being delivered through lessons
d) To establish the attainment of the STEM Education Curriculum by the learners.

Critical observations and analysis of the general status of the school, planning for lessons and delivery of lessons gave enough data and evidence on the organization, management and operation of STEM Education in the schools visited. This was to necessitate provision of early interventions from emerging issues and to plan for assessment of learning.

The research found that, there were remarkable efforts shown by Teachers, Heads of Departments and School Administrators in implementing STEM Education in the schools. Based on the research findings, in the context of the School Environment, it can be concluded that there was generally unavailability of specialized rooms especially Mathematics and Agricultural Science laboratories. Further, in terms of human resource there were qualified Managers, Management teams & teachers. However, it was discovered that there was generally low staffing levels in Design and Technology, and Hospitality and Tourism Departments. Furthermore, the Hospitality and Tourism Curriculum Pathway was least offered in Provincial STEM schools.

In addition, in the context of Curriculum intentions and implementation there was average understanding of STEM Education Curriculum intentions and implementation by teachers because in some cases there was remarkable understanding of Curriculum dictates whilst in other cases misapprehensions of Curriculum intent was dominant. Further, progressive strides from positivism to constructivism in lesson delivery was demonstrated as in some lessons outstanding constructivist pedagogical tenets where exhibited whereas in others there were struggles to shift from domineering positivist tendencies. To this effect, it was not surprising to find that in the context of Planning for teaching, Textbooks influenced planning characterised by inadequate time spent on planning for lessons. Furthermore, the STEM Education Curriculum intentions were mostly not adequately understood and interpreted. On teacher competency and skills the research noted the inadequate study of teaching & learning materials to enhance effective planning. All these greatly affected the delivery resulting in constructivist flow of activities fairly being exhibited in some lessons where in some cases there was inability to conclude lessons effectively. All these pointed to the teachers' struggles to shift from positivist to constructivist approaches as proposed by the STEM Education Curriculum.

As regards Curriculum attainment, the research found that it was partial for the reason that only development of some Scientific Skills was displayed with no learner progression information yet documented. This area of focus in the study showed the following characteristics; Workbooks not utilized, Research & Continuous Assessment not yet commenced, Acquisitive, Organizational & Communicative skills remarkably exhibited in lessons, and Creative & Manipulative Skills inadequately demonstrated in lessons. The research findings therefore have implications on; STEM Education policy, STEM Education research, Practice (teaching and learning)-Curriculum intentions may not be adequately realized. Further it point to; STEM Education Curriculum Organization, hence Learner may not develop the desired STEM competences and mostly the Teacher requiring reorientation and structuring to suit the new demand of teaching.

In conclusion, on one hand, the positive strides in the implementation of STEM Education Curriculum implied that there was guarantee to equip Zambian STEM learners with learning, life, and media literacy skills, which are important attributes in contemporary society. On the other hand, the inadequacies suggested impediments in attainment of Curriculum intentions. In order to reach desirable levels of STEM Education implementation, it is therefore, recommended that there be targeted interventions such as; sustainable in-service capacity building of school administrators, STEM teachers and trainers in Pedagogical Content Knowledge, STEM Curriculum content readjustments and review as well as, to a greater extent, continued support of STEM Education.

Background: This research endeavoured to assess the STEM Education implementation in the 15 STEM Secondary schools following the commencement of the 2019 Transitional STEM Education in Zambia

Action

Table 21: STEM Education Intentions Implementation and Attainment

S/N	Area of Assessment Focus	Policy Objective	Observations	Recommendations		
				Policy Level	**Practice Level**	**Institutional Level**
1.	**School Environment**	***To create an Environment conducive for teaching and learning in STEM Education***	Unavailability of specialized rooms especially Libraries and Mathematics and Agricultural Science laboratories	Develop specialized rooms and electronic Libraries	Facilitate development of specialized rooms and electronic Libraries	Construct specialized rooms especially Mathematics and Agricultural Science laboratories and setup electronic libraries
			Qualified Managers, Management teams & teachers	Recruit and re-align Suitably Qualified Managers, Management teams & teachers	Recruit and re-align Suitably Qualified Managers, Management teams & teachers	Lobby for suitably qualified staff according to career pathways implemented.
			Low staffing levels in Design & Technology, and Hospitality & Tourism Departments	Recruit and re-align adequate and appropriate teachers in STEM schools	Recruit and re-align adequate and appropriate teachers in STEM schools	Lobby for adequate staff in Design & Technology, and Hospitality & Tourism Departments

S/N	Area of Assessment Focus	Policy Objective	Observations	Recommendations		
				Policy Level	**Practice Level**	**Institutional Level**
		To Implement STEM pathways based on geographical leverages without gender categorization	Hospitality and Tourism Curriculum Pathway least offered in Provincial STEM schools	Implement pathways without gender categorization	Support STEM Schools to implement pathways without categorization by gender	Offer Hospitality and Tourism Curriculum Pathway in Provincial STEM schools without gender categorization
2.	**Planning for lesson**	***To develop-teachers' skills and competences in planning for STEM teaching and learning***	(i)Textbooks influenced planning	Encourage the development of teachers' skills and competences	Facilitate development of teachers' skills and competences	Conduct lessons based on curriculum intentions
			Inadequate time spent planning for lessons	Strengthen the development of teachers' skills and competences	Facilitate development of teacher's skills and competences.	Conduct CPD activities in planning for lessons
			Intentions not adequately understood and interpreted	Strengthen the development of teachers' skills and competences	Facilitate development of teachers' skills and competences	Conduct CPD to enhance understanding & interpretation of STEM curriculum intentions
			Inadequate study of teaching & learning materials to enhance effective planning	Develop teachers' skills and competences	Strengthen teachers' skills and competences	Conduct CPD on the study of teaching and learning materials

S/N	Area of Assessment Focus	Policy Objective	Observations	Recommendations		
				Policy Level	Practice Level	Institutional Level
						for effective planning
3.	**Delivery of lesson**	***To promote high levels of skills and competences in the use of constructivists theory in the teaching and learning of STEM subjects***	Constructivist flow of activities fairly exhibited in some lessons	Promote teachers' skills and competences in use of constructivism approach in lesson delivery	Develop teachers' skills and competences in use of constructivism approach in lesson delivery	Conduct STEM lessons that enhance constructivist flow of activities.
			Struggles to shift from positivist to constructivist approaches	Promote teachers' skills and competences in use of constructivism approach in lesson delivery	Develop teachers' skills and competences in use of constructivism approach in lesson delivery	Conduct STEM lessons that enhance shift from positivist to constructivist approaches.
			Inability to conclude lessons effectively	Promote teachers' skills and competences	Develop teachers' skills and competences in effective lesson delivery	Conduct lessons that enhance ability to conclude lessons effectively
4.	**Attainment of curriculum intentions**	***To develop high levels of skills and competences in Teaching Learning Materials management***	Workbooks not utilized	- Promote formulation of guidelines on management and utilization of workbook	- Develop guidelines on the management and utilization of workbook	- Institutionalize, management and utilization of workbook

S/N	Area of Assessment Focus	Policy Objective	Observations	Recommendations		
				Policy Level	**Practice Level**	**Institutional Level**
		and application of Scientific skills	Creative and Manipulative skills inadequately demonstrated in lessons	- Promote scientific skills	- Enhance scientific skills	- Conduct lessons that activate and foster creative and manipulative skills
			Acquisitive, Organizational and Communicative skills remarkably exhibited in lessons	- Strengthen scientific skills	- Enhance scientific skills	- Conduct lessons that foster acquisitive, organizational and communicative skills.
		To develop guidelines for research and assessment	Research and Continuous Assessment not yet commenced	Develop guidelines for research and assessment	Facilitate implementation of guidelines for research and school-based assessment	Commence research and School Based Assessment (SBA)
5.	**Implications of implementation of STEM Education**	***To analyse implications due to unavailability of key ingredients of STEM Education implementation***	STEM Education policy	Develop STEM Education Policy	Facilitate Development of STEM Education Policy	Accurately interpret and implement STEM Education Policy
			STEM Education research	Develop guidelines on research	Facilitate implementation of guidelines for research	Conduct research based on the guidelines

S/N	Area of Assessment Focus	Policy Objective	Observations	Recommendations		
				Policy Level	Practice Level	Institutional Level
			Practice (teaching and learning)- Curriculum intentions may not be adequately realized	Promote-teachers' skills and competences .	Facilitate the development of teachers' skills and competences	Conduct CPD on the understanding of curriculum intentions and implementation.
			STEM Education Curriculum Organization	Establish the organization of the STEM Education curriculum	Enhance the development and organization of STEM Education curriculum	Manage and coordinate education curriculum organization
			Learner – M ay not develop the desired STEM competences	Promote the use of constructivist methodologies to develop a learner who is CCAT	facilitate use of constructivist methodologies to develop a learner who is CCAT	Implement lessons using the constructivist methodologies

PROPOSED POLICY STATEMENT

1. The government shall strengthen STEM education by creating a conducive school environment, that will offer sound quality STEM education through devoting more resources and time, recruiting and retaining high performing learners and teachers capable of attaining outcome-based education that will help to effectively exploit locally available resources through critical, creative and analytical areas in both technical and scientific manner for national development through self-reliance.
2. The government shall strengthen STEM education by creating a conducive school environment, that will offer sound quality STEM education through devoting more resources and time to retaining high performing learners and teachers capable of attaining outcome-based education that will help to effectively exploit locally available resources through critical, creative and analytical areas in both technical and scientific manner for national development through self-reliance.

3. The government shall strive to create an Environment conducive for teaching and learning in STEM Education through construction of specialised rooms and setting up electronic libraries, recruitment and deployment of adequately and appropriately qualified staff and implementing STEM pathways based on geographical leverages without gender categorization
4. The government shall develop-teachers skills and competences in effective planning and delivery of STEM teaching and learning through use of constructivists pedagogies and strengthening research, assessment and application of scientific skills for the 21^{st} Century learner (The government shall develop-teachers skills and competences in effective planning and delivery of teaching and learning in STEM Education through use of constructivists pedagogies and strengthening research, assessment and application of scientific skills for the 21^{st} Century learner).

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Appendices

Appendix 1: Workbook – Teachers and Learners Roles

Workbook characteristic	Teachers role	Learners role
Provided and Owned by the Learner or Institution	• Ensure that all learners have their workbooks • Orient the learner on the importance and content of workbook • Where appropriate provide relevant workbook for learners • Develop own workbook for cross referencing	• Acquire workbooks in each subject and one for research • Appreciate the importance of workbook
Notes are Co-developed by Learner and Teacher	• Develop the notes for the teacher for cross referencing • Ensure that learners construct their notes either in soft or hard copy	• Develop own notes either in soft or hard copy
Comes with Variety in Structure and Approaches	• Develop varieties of workbook structures • Use variety of approaches	• Develop varieties of workbook structures • Use variety of approaches • Process Triggered by Teacher, Driven
Process Triggered by Teacher, Driven by Learner, Validated by Teacher and Owned by Learner	• Trigger what is to be written in the workbooks • Support and validate the learner workbook progress	• Account for all the tasks to be written in the workbooks • Ensure work is validated and advice adhered to, if any
Learners are Continuously Critical, Creative and Analytical Thinkers	• Create an enabling environment for CCAT to thrive in learners	• Develop and display CCAT competencies and skills

Workbook characteristic	Teachers role	Learners role
Constructivist in Nature	• Create appropriate tasks that conform with constructivist approaches • Facilitate and support learning	• Work on tasks and activities diligently in conformity with constructivist approaches
Major Learner Input and Ownership	• Develop competencies and skills in learners to manage the workbook	• Own the workbook • Manage the workbook effectively by documenting all necessary activities
Learner Dependent	• Facilitate ownership in workbook management by learner • Check what learners are depositing in their workbooks	• Be the main driver of what goes in the repository • Regularly submit the workbook for checking
Variety, Diverse, Multiple Viewpoints on a Concept	• Expose learners to variety of viewpoints on a concept • Encourage collaboration and team work among learners • Create tasks that result in multiple viewpoints	• Use a variety of viewpoints on a concept • Collaborate with other learners for unity of purpose
Assessment Made in Line with Learner Progression	• Design assessment tasks to be given to leaners • Check the progress and provide support during the execution of the learners' tasks • Document the assessment of the learners	• Work on assessment tasks given • Document worked solutions and activities • Submit worked solutions and activities for assessment • Record assessment scores
Research-based Learning	• Introduce the layout of research stages and major components of research paper • Facilitate the choice of research topics • Provide support during the research process • Assess and document research activities at various stages	• Understand and implement research • Regularly submit research activities (including write-ups) for checking at various stages

Workbook characteristic	Teachers role	Learners role
Learner Progression Determine the Learning Pace	• Appreciate the fact that all learners are able and understand their individual levels of capability • Encourage learners to be assertive • Provide individualized support during the learning process • Assess the learner progression at different stages	• Work independently and in collaboration with others • Be assertive
Cumbersome but inevitable process	• Deepen the pedagogical understanding on effective constructivist approaches • Make learners appreciate the bulky tasks and activities to be undertaken and documented • Develop organizational skills in learners	• Appreciate the bulky tasks and activities to be undertaken and documented • Develop organizational skills
Requires Skills and Competencies	• Develop Scientific Skills in oneself and learners • Assess Scientific Skills in learners using the workbook	• Develop Scientific Skills in oneself

***Appendix* 2: List of STEM Schools Observed**

S/No.	Name of STEM School
1.	Chiwala Boys Provincial STEM School
2.	Chizongwe Boys Provincial STEM School
3.	David Kaunda National STEM School
4.	Edgar Lungu National STEM School
5.	Hillcrest Boys National STEM School
6.	Kambule Boys Provincial STEM School
7.	Kapiri Girls Provincial STEM School
8.	Kenneth Kaunda Provincial STEM School
9.	Mungwi Provincial STEM School
10.	Musonda Girls Provincial STEM School
11.	Ndola Girls National STEM School
12.	Nikko Provincial STEM School
13.	Rufunsa Girls Provincial STEM School
14.	Serenje Boys STEM School
15.	Solwezi Boys Provincial STEM School

Appendix 3: Research Weight Allocation

1. Layout	**Detailed description**	**Weight allocation**
	Sequential logical flow comprising the following: (Title, Abstract, Introduction/Background, Objectives/Research Questions, Problem Statement, Literature Review, Methodology, Results/Findings, Conclusion, Recommendations, References	1.2
	Title	1.2
	Abstract *(purpose of study, research gap, methodology, major findings, implications, recommendations, key terms – 3 to 5, 250 words)*	2.4
	1. Introduction/Background	2.4
	i. Objectives/Research Questions	2.4
	ii. Problem Statement	2.4
	2. Literature Review	2.4
	3. Methodology	2.4
	4. Results/Findings	2.4
	5. Discussions 6. Conclusion	1.2
	7. Recommendations	1.2
	8.References – quality of reference (APA)	1.2
2.Formatting	Font type – Times new Roman	1.2
	Font size – 12 points	1.2
	Line spacing – 1.5	1.2
	Page numberings	1.2
Total		30

Appendix 4: Data Collection Tools

Scientific Skills Consolidated											
	School	Subject	Grade	**Manipulative Skills**							
				Using, handling & maintaining instruments	Demonstrating	Experimenting	Constructing	Calibrating	Measuring & using numbers	Controlling variables	Handling specimen correctly & carefully
Central and Luapula											
Copperbelt and North Western											
Southern and Western											
Eastern and Lusaka											
Muchinga and Northern											

Scientific Skills Consolidated									
	School	Subject	Grade	**Creative Skills**					
				Planning ahead	Designing	Inventing	Synthesising	Formulating Models	Sketching specimen & apparatus
Central and Luapula									
Copperbelt and North Western									
Southern and Western									
Eastern and Lusaka									
Muchinga and Northern									

Scientific Skills Consolidated														
	School	Subject	Grade	**Organizational Skills**										
				Recording	Comparing	Contrasting	Organising	Outlining	Reviewing	Evaluating	Analysing	Predicting	Inferring	Interpreting Data
Central and Luapula														
Copperbelt and North Western														
Southern and Western														
Eastern and Lusaka														
Muchinga and Northern														

Scientific Skills Consolidated												
	School	Subject	Grade	**Acquisitive Skills**								
				Listening	Observing	Searching	Inquiring	Investigating	Gathering Data	Researching	Defining operationally	Formulating hypotheses
Central and Luapula												
Copperbelt and North Western												
Southern and Western												
Eastern and Lusaka												
Muchinga and Northern												

STEM Curriculum Intentions and Implementation											
Planning for lessons	**Lesson in Relation to Curriculum Intentions**										
	School	Subject	Grade	Topic		Sub-Topic		Outcome		Knowledge	
				In line with	Not in line	In line with	Not in line	In line with	Not in line	In line with	Not in line
Central and Luapula											
Copperbelt and North Western											
Southern and Western											
Eastern and Lusaka											
Muchinga and											

Northern												

STEM Curriculum Intentions and Implementation						
Planning for lessons	**Lesson Plan Format**					
	Individual	Collaborative	Plan to clear misconceptions	Assessment Criteria	Lesson Template	
					Open	Pre-Designed
Central and Luapula						
Copperbelt and North Western						
Southern and Western						
Eastern and Lusaka						
Muchinga and Northern						

STEM Curriculum Intentions and Implementation										
Planning for lessons	**Rationale**									
	Content		Importance		Methodology			Position		Comment
	Indicated	Not Indicated	Indicated	Not Indicated	Not Indicated	Indicated	Type	Indicated	Not Indicated	
Central and Luapula										
Copperbelt and North Western										
Southern and Western										
Eastern and Lusaka										
Muchinga and Northern										

STEM Curriculum Intentions and Implementation						
	Plan for Introduction					
	Scenario		Problem Statement		Key Question	
Planning for lessons	Appropriate	Not Appropriate	Appropriate	Not Appropriate	Appropriate	Not Appropriate
Central and Luapula						
Copperbelt and North Western						
Southern and Western						
Eastern and Lusaka						
Muchinga and Northern						

STEM Curriculum Intentions and Implementation							
	Plan for Development				Plan for Conclusion		
	Activities		Consolidation	Comments	Summary	Evaluation	Comment
Planning for lessons	Constructivism	Positivism					
Central and Luapula							
Copperbelt and North Western							
Southern and Western							
Eastern and Lusaka							
Muchinga and Northern							

STEM Curriculum Intentions and Implementation							
Resource Materials	School	Subject	Grade	Name of Resource Material	Indicated		Not Indicated
					Appropriate	Not Appropriate	
Central and Luapula							
Copperbelt and North Western							
Southern and Western							
Eastern and Lusaka							
Muchinga and Northern							

STEM Curriculum Intentions and Implementation									
Teaching and Learning Aids Preparation	School	Subject	Grade	Not Indicated	Indicated	Type	Usage		Comment
							Teacher	Learner	
Central and Luapula									
Copperbelt and North Western									
Southern and Western									
Eastern and Lusaka									
Muchinga and Northern									

STEM Curriculum Delivery								
Lesson Delivery	School	Subject	Grade	**Introduction**				
				Appropriate	Not Appropriate	Key Task		Comments
						Not Presented	Presented (Verbally or written)	
Central and Luapula								
Copperbelt and North Western								
Southern and Western								
Eastern and Lusaka								
Muchinga and Northern								

STEM Curriculum Delivery								
Lesson Delivery	**Development**							
	Strategies		Flow of Activities			Consolidation		
	Group Work	Individual	Constructivist	Positivist	Comment	Done	Not Done	Comment
Central and Luapula								
Copperbelt and North Western								
Southern and Western								
Eastern and Lusaka								
Muchinga and Northern								

STEM Curriculum Delivery					
Lesson Delivery	**Conclusion**				
	Summary		Evaluation		Comment
	Done	Not Done	Done	Not Done	
Central and Luapula					
Copperbelt and North Western					
Southern and Western					
Eastern and Lusaka					
Muchinga and Northern					

STEM Curriculum Delivery								
Teaching and Learning Aids Utilization	School	Subject	Grade	**Teaching Learning Aids**				
				Indicated on the Lesson Plan	Utilized in the Lesson	Prescribed by Teacher	Prescribed by Learners	Comment
Central and Luapula								
Copperbelt and North Western								
Southern and Western								
Eastern and Lusaka								
Muchinga and Northern								

STEM Curriculum Attainment					
Research	School	Grade	**Research Lessons**		
			Started	Not Started	Comment
Central and Luapula					
Copperbelt and North Western					
Southern and Western					
Eastern and Lusaka					
Muchinga and Northern					

STEM Curriculum Attainment						
School Based Assessment	School	Grade	Subject	**Records of Assessment**		Comment
				Present	Not Present	
Central and Luapula						
Copperbelt and North Western						
Southern and Western						
Eastern and Lusaka						
Muchinga and Northern						

Scientific Skills Consolidated												
	School	Subject	Grade	**Communicative Skills**								
				Questioning	Discussing	Explaining	Reporting	Writing	Critiquing	Graphing	Teaching	Communicating
Central and Luapula												
Copperbelt and North Western												
Southern and Western												
Eastern and Lusaka												
Muchinga and Northern												

Appendix 6: Minor Research Weight Allocation

S/N	Detailed Description	Weight Allocation	
A.	**Sequential logical flow**		
	Title	0.9	
	Abstract *(purpose of study, research gap, methodology, major findings, implications, recommendations, key terms – 3 to 5, 250 words)*	1.6	
	1. Introduction/Background	1.6	
	i. Objectives/Research Questions	1.6	
	ii. Problem Statement	1.6	
	2. Literature Review	1.6	
	3. Methodology	1.6	
	4. Results/Findings	1.6	
	5. Discussions	1.6	
	6. Conclusion	0.9	
	7. Recommendations	0.9	
	8. References – quality of reference (APA)	0.9	
	Subtotal		**16.4**
B.	**Formatting**		
	Font type – Times new Roman	0.9	
	Font size – 12 points	0.9	
	Line spacing – 1.5	0.9	
	Page numberings	0.9	
	Subtotal		**3.6**
	Total		**20**

Appendix 7: Major Research Weight Allocation

S/N	Detailed Description	Weight Allocation	
A.	**Sequential logical flow**		
	Title	1.2	
	Abstract *(purpose of study, research gap, methodology, major findings, implications, recommendations, key terms – 3 to 5, 250 words)*	2.4	
	1. Introduction/Background	2.4	
	i. Objectives/Research Questions	2.4	
	ii. Problem Statement	2.4	
	2. Literature Review	2.4	
	3. Methodology	2.4	
	4. Results/Findings	2.4	
	5. Discussions	3.6	
	6. Conclusion	1.2	
	7. Recommendations	1.2	
	8. References – quality of reference (APA)	1.2	
	Subtotal		**25.2**
B.	**Formatting**		
	Font type – Times new Roman	1.2	
	Font size – 12 points	1.2	
	Line spacing – 1.5	1.2	
	Page numberings	1.2	
	Subtotal		**4.8**
	Total		**30**