THIRD COUNTRY TRAINING PROGRAMME

IMPROVING THE QUALITY OF LEARNING OF MATHEMATICS AND SCIENCE THROUGH THE USE OF 5E INSTRUCTIONAL MODEL IN INQUIRY BASED LEARNING

Training Module – Secondary

CEMASTE A –NAIROBI, KENYA 2017
5th - 18th September 2017
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>iv</td>
</tr>
<tr>
<td>SYMBOLS</td>
<td>iv</td>
</tr>
<tr>
<td>FOREWORD</td>
<td>v</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>vi</td>
</tr>
<tr>
<td>MODULE OBJECTIVES AND GOALS</td>
<td>7</td>
</tr>
<tr>
<td>INTRODUCTORY UNIT: FEEDBACK AND EXPERIENCE SHARING</td>
<td>8</td>
</tr>
<tr>
<td>UNIT ONE: INQUIRY-BASED LEARNING IN MATHEMATICS AND SCIENCE</td>
<td>10</td>
</tr>
<tr>
<td>UNIT TWO: DEMONSTRATION LESSON</td>
<td>22</td>
</tr>
<tr>
<td>UNIT THREE: 5E INSTRUCTIONAL MODEL</td>
<td>24</td>
</tr>
<tr>
<td>UNIT FOUR: SUBJECT BASED SESSIONS</td>
<td>30</td>
</tr>
<tr>
<td>BIOLOGY</td>
<td>30</td>
</tr>
<tr>
<td>Topic One: Nutrition in Plants and Animals</td>
<td>30</td>
</tr>
<tr>
<td>Topic Two: Respiration</td>
<td>39</td>
</tr>
<tr>
<td>CHEMISTRY</td>
<td>49</td>
</tr>
<tr>
<td>Topic One: Salts</td>
<td>49</td>
</tr>
<tr>
<td>Topic Two: Structure and Bonding</td>
<td>57</td>
</tr>
<tr>
<td>MATHEMATICS</td>
<td>65</td>
</tr>
<tr>
<td>Topic One: Fractions</td>
<td>65</td>
</tr>
<tr>
<td>Topic Two: Vectors</td>
<td>79</td>
</tr>
<tr>
<td>PHYSICS</td>
<td>103</td>
</tr>
<tr>
<td>Topic One: Particulate Nature of Matter</td>
<td>103</td>
</tr>
<tr>
<td>Topic Two: Linear motion</td>
<td>112</td>
</tr>
<tr>
<td>UNIT FIVE: LESSON OBSERVATION</td>
<td>120</td>
</tr>
<tr>
<td>UNIT FIVE: EFFECTIVE IMPLEMENTATION ON INQUIRY-BASED LEARNING</td>
<td>130</td>
</tr>
<tr>
<td>CONCLUDING UNIT: ACTION PLANNING</td>
<td>132</td>
</tr>
</tbody>
</table>
LIST OF ABBREVIATIONS

ASEI  Activity Student Experiment Improvisation
PDSI  Plan, Do, See and Improve
CEMASTEA  Centre for Mathematics, Science and Technology Education in Africa
INSET  In-service Education and Training
JICA  Japan International Cooperation Agency
TCTP  Third Country Training Programme
SMASE  Strengthening of Mathematics and Science Education
WECSA  Western, Eastern Central and Southern Africa
SEAMEO  Southeast Asian Ministers of Education Organization Regional Centre for
          Education in Science and Mathematics
RECSAM)  Inquiry Based Learning
IBL  Inquiry Based Learning
5E  Engagement, Exploration, Explanation, Elaboration and Evaluation

SYMBOLS

| Symbol | Meaning
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Reflection" /></td>
<td>Participants to reflect on the issues at hand either individually or in groups. Guidance will be provided by the facilitators.</td>
</tr>
<tr>
<td><img src="image" alt="Participants" /></td>
<td>Participants to work and report on a given activity as a group.</td>
</tr>
<tr>
<td><img src="image" alt="Question" /></td>
<td>A question to be answered by participants. They may work on the questions either individually or in groups. Guidance will be provided by the facilitators.</td>
</tr>
<tr>
<td><img src="image" alt="Enclosure" /></td>
<td>Enclosure for activity to be worked on by participants either individually or in groups or possible responses to a question posed. Used in combination with other symbols.</td>
</tr>
<tr>
<td><img src="image" alt="Expected" /></td>
<td>Expected or possible responses to a question posed</td>
</tr>
</tbody>
</table>
FOREWORD

Center for Mathematics Science and Technology Education in Africa (CEMASTEA) is an institution set up by the Government of Kenya with the support of the Government of Japan to provide In-Service Education and Training (INSET) to teachers of science and mathematics. Since inception in the year 2003, the Centre has planned and implemented capacity development programmes for teachers of mathematics and science and, key stakeholders in the education sector both in Kenya and other African countries.

CEMASTEA is again honored to host the Third Country Training Programme (TCTP) 2017 with the sponsorship of JICA and the Ministry of Education Kenya. The theme for TCTP this year ‘Use of 5E Instructional Model in Inquiry Based Learning in Teaching and Learning of Mathematics and Science’. TCTP 2017 targets are practicing INSET providers who serve as trainers for primary mathematics and science teachers at national or regional level. The course provides participants with a platform for sharing promising classroom experiences, knowledge and pedagogical skills to improve the teaching and learning of mathematics and science.

As with our previous training, the approach used in this module is interactive, with a special focus on concept, meaning and the practice of Inquiry-Based Learning (IBL) in teaching and learning and the role the 5E instructional model could play in making the IBL successfully implemented. The course takes two weeks with participants taking part in individual reflections, plenary interactions, group discussions, hands-on activities, lesson planning, peer teaching and, actual classroom practice. Module units emphasize specific teaching and learning outcomes relating to Inquiry-Based Learning and 5E instructional and peer lesson evaluation.

Upon completion of this course, I believe participants will be enriched in knowledge, skills, and attitudes to plan and implement and even train others on inquiry-based learning and peer lesson evaluation.

Enjoy your learning.

Stephen M. Njoroge
Director, CEMASTEA
ACKNOWLEDGEMENTS
The Director, CEMASTEA would like to thank the following people for the hard work they put into the development of this module.

Stephen M. Njoroge  Mathematics Education  Director, CEMASTEA
Moses O. Kawa  Biology Education  Deputy Director, CEMASTEA
Lee Shok Mee  Consultant  SEAMEORECSAM, Malaysia
Joseph Mathenge  Chemistry Education  Coordinator, Training Programmes
Mary Kariuki  Biology Education  Coordinator, Performance Contracting
Thuo Karanja  Biology Education  Coordinator, International Training
Pricilla Ombati  Mathematics Education  Deputy Coordinator, International Training
John Makanda  Physics Education  Coordinator Secondary Programmes
Grace Orado(Dr.)  Chemistry Education  Coordinator, Research, and Development
Kizito Makoba  Biology Education  Dean, Biology Education
David Arimi  Biology Education
Amina Sharbaidi  Biology Education
Kennedy Otieno  Biology Education
Kiyapi Catherine  Ministry of Education
Daniel Matiri  Chemistry Education  Coordinator, TCTP 2017 (Secondary)
Ernest Ngeny  Physics Education  Dean, Physics Education
Gladys Masai  Chemistry Education  Coordinator, ISO
Okeyo R. Jakomanyo  Chemistry Education
Nanacy Nui  Mathematics Education  Dean, Mathematics
Simon Mugo  Mathematics Education
Francis Kamau  Mathematics Education
Paul Kibanya  Physics Education
Kibe Samuel  JICA, Kenya Office
Nakajima Motoe  JICA Regional Coordinator
Paul Akoko  Biology Lab Assistant
Omweri Mokaya  Chemistry Lab Technician
Faith Muchiri  Administration
Ann Jane Mumbi  Editor
Paul Lumosi  ICT Lab Technician
Jane Marete  Administration
Rose Muhoro  Transport

Stephen M. Njoroge  
**Director, CEMASTEA**
MODULE OBJECTIVES AND GOALS

Welcome to this module on ‘Improving the quality of learning of mathematics and science through the use of 5E Instructional Model in Inquiry Based Learning (IBL)’. This module will provide you with an opportunity to understand and practice 5E Instructional Model in Inquiry Based Learning. The module is divided into seven units. Unit one on the meaning and concept of Inquiry Based Learning, unit two on lesson demonstration and unit three is on the 5E instructional model. Unit four focus on subject-based content where you will carry out activities derived from Biology, Chemistry, Physics and Mathematics. Unit five focus on lesson evaluation where you will get the opportunity to apply the lesson observation skills in IBL. Unit six in of Effectives implementation of IBL in schools while Unit seven in; the last unit a reflection on training and thinking of how to effectively adapt IBL and 5E instructional model through action planning. As you go through the training, we encourage you to reflect on how lessons learnt continually could be implemented in your home country.

Module Goal
Improving the quality of learning of mathematics and science through the use of 5E Instructional Model in Inquiry Based Learning

Module Objectives: The objectives of this module are to enhance participants’ ability:-
1. In the use Inquiry Based Learning in teaching and learning science and mathematics
2. In using the 5E instructional model in IBL in teaching and learning in science and mathematics
3. To evaluate lessons for improved quality of teaching and learning in science and mathematics

Expected Learning Outcomes
Upon completion of this Module, you should be able to apply and demonstrate the use of the 5E instructional model in Inquiry-Based Learning.
INTRODUCTORY UNIT: FEEDBACK AND EXPERIENCE SHARING

Introduction
Welcome to this session. In this session, we will share country teacher capacity developments programmes, experiences on implementation of mathematics and science activities and on seminars conducted in your respective countries after Third Country Training Program (TCTP) training at CEMASTEA. TCTP training have aimed at enhancing classroom practices, classroom supervision, and teacher continuous professional development, among others. The training have always been tailored to meet various countries’ needs. Country feedback and sharing experiences will help to strengthen the countries’ collaboration on mathematics and science activities.

Rationale
Teacher Continuous Professional Development (TCPD) is important in improving classroom practice. CEMASTEA has so far conducted 34 (Thirty four) TCTP pieces of training since 2004. By the end training, participants come up with action plans on how they will implement knowledge and skills acquired in their respective countries. Thus, this session provides you with an opportunity to share your experiences from your Countries on the implementation of mathematics and science activities.

Unit Goal
Share findings and experiences during implementation of mathematics and science activities in your various countries

Unit Objectives: By the end of the session, you should be able to s
1) Share your experiences on
   a) individual Country based TCPD programs
   b) Personal involvement in the TCPD
   c) Application of knowledge and skills gained during TCPD.
2) Appreciate the importance of TCPD in enhancing classroom practices, classroom supervision and implementation of mathematics and science activities.

Learning outcome
Improved implementation of experience sharing seminars and related activities

Feedback on teachers’ continuous professional development
It is expected that there are institutionalized teachers’ continuous professional development programmes in your country. Moreover, after attending TCTP training at CEMASTEA, you are expected to conduct experience sharing seminars in your countries. We therefore welcome you to give feedback on experience sharing seminars you conducted/attended and mathematics and science activities taking place in your respective countries.
Activity
Share your country’s experiences on:
   a) Teacher Continuous Professional Development (TCPD) activities in mathematics and science being implemented in your countries
   b) Personal involvement in the TCPD including experience sharing seminar held after TCTP training at CEMASTEA
   c) Application of knowledge and skills acquired during TCPD training

Conclusion
Sharing of experiences on implementation of activities in mathematics and science education from different countries would give you an opportunity to learn from experiences of other countries. This may further enhance your knowledge and skills in implementation of teaching and learning activities in mathematics and science. Moreover, it will provide you with an opportunity to learn different ideas and adapt them in your existing mathematics and science programmes.
UNIT ONE: INQUIRY-BASED LEARNING IN MATHEMATICS AND SCIENCE

Introduction
Welcome to this unit which is the second unit of this module. In this unit, you will share experiences and enhance your ability to enact teaching that involves inquiry-based learning in mathematics and science. The unit is divided into six sections. Section one gives the preliminaries of the unit which include: rationale, unit goal, unit objectives, and unit outcome. Section Two which is the general session of this unit introduces you to the unit content which includes the idea of inquiry in general and inquiry in learning. It also describes the process of inquiry-based learning and provides examples of inquiry-based learning activities in mathematics and science. Also included in this section is an activity that will accord you an opportunity to observe and evaluate a demonstration-lesson for aspects of the inquiry. Sections Three, Four, Five and Six will focus on subject based activities involving inquiry-based learning.

Rationale
The training report for TCTP 2015 and the Africa Policy Research (2015) conducted in countries that participate in Third Country Training Programme (TCTP) since 2004 show that the teaching and learning of mathematics and science are still to a large extent teacher-centred. CEMASTEA as an institution for teacher capacity development emphasises the use of Activity, Student, Experiment and Improvisation- Plan, Do, See and Improve (ASEI-PDSI) principles in teaching and learning of mathematics and science. The main idea behind these principles is the need for students to be involved in the learning process through well planned lesson activities. Just like ASEI-PDSI principles, inquiry-based learning is a teaching strategy that allows learners to take control of their own learning (Carin & Bass, 2001). This implies that inquiry-based learning is consistent with the principles of ASEI-PDSI. When learners are given an opportunity to learn the content in school curriculum through inquiry their ability to develop a variety of skills that include, questioning, predicting, observing, manipulating and inferring is enhanced. It is therefore important for teachers to build their capacities and abilities in enacting teaching that incorporates inquiry-based approaches. This unit introduces you to the idea of teaching mathematics and science through inquiry-based approaches and accords you opportunities to experience inquiry learning in mathematics and science.

Unit Goal
The goal of this unit is to enhance your ability to use inquiry-based learning strategies in your teaching.

Unit Outcome
Demonstrate competence in developing lesson activities that are inquiry-based in nature.
Unit Objectives
To enhance your ability to:

a). Develop lesson activities where learners learn through inquiry-based learning.

b). Evaluate lessons for their effectiveness in helping learners learn through inquiry-based learning.

c). Appreciate the need for learners to learn through inquiry-based approaches

Section Two: Unit Content
Inquiry-based Learning
Let us begin by reflecting on the meaning of the term inquiry. Could you please think and give a response to the following question?

Activity 1.1
What do you understand by the term inquiry?

You may have come up with the following responses:

- an act of finding out about something,
- an act of seeking for information,
- an act of asking questions

Based on these responses, it can be seen that inquiry is an integral part of human life. In their everyday interactions people seek for information or ask questions about people or things. For example, a person may ask how long it will take a bus s/he has boarded to travel from one town to another, how to navigate from one part of unfamiliar town to another, or how often vehicles ply a given route. Seeking for information may help people plan for activities in their everyday lives more effectively. For example, knowing the time a bus would arrive at a given destination would be important because it can help in planning ahead of time for pick up by a friend or relative, or estimate the time that a person can commit to other activities upon arrival in the next town.

In a learning situation, inquiry goes beyond seeking for information. What does inquiry-based learning entail? Discuss the following question with the person seated next to you.

Activity 1.2
What does inquiry-based learning involve?

You may have come up with the following responses:

- learning learn through conducting investigations to help answer certain questions,
- learning that involves designing experiments,
- learning that allows questions to be asked and activities designed to answer the
Inquiry-based learning is widely accepted as a method of teaching and learning that places students’ questions, ideas and observations at the centre of the learning experience. Through inquiry-based learning, learners are engaged in authentic investigations in which they identify problems, ask questions, propose solutions, make predictions, design procedures, collect, and organize data, and draw conclusions. In enacting teaching that embraces this method, Scardamalia (2002) argues for the need for teachers to establish a classroom culture where ideas are respectfully challenged, tested, redefined, and viewed as improvable. He further notes that the culture in the classroom should be one that allows moving children from a position of wondering to a position of understanding and further questioning. Based on this argument, it seems that raising questions and working towards looking for solutions to the questions are important components of teaching that embraces inquiry-based learning. Besides raising questions, other components of inquiry-based teaching and learning includes data collection, data analysis and drawing of conclusions. The figure below illustrates the process of inquiry-based learning.

![Process of inquiry-based learning](http://www.inquiry.uiuc.edu/index.php)

Based on Figure 1, inquiry-based learning is a systematic process which begins with framing the investigation by identifying the questions to be answered. This is then followed by designing the investigation, collecting and presenting data. The data are then analyzed and the results interpreted. The final stage in inquiry-based learning is reflecting about the inquiry activity with a view to engaging in further investigations.

**Types of Inquiry-based Learning**
Inquiry-based learning can be confirmatory, structured, guided or open.

1. **Confirmatory inquiry** - In this kind of inquiry, the teacher has absolute control over every phase of the process, and makes all the decisions. Students are provided with the question to be answered and the procedure as well as the results of an investigation. The teacher also provides all the necessary information, materials and apparatus and asks the students to carry out the procedure. The following are examples using content from biology, chemistry, mathematics and physics.

   **a) Biology**
   Let us consider an example in Biology using the concept of photosynthesis.
   
   **Question**: What is the effect of light on the rate of photosynthesis?
   
   **Procedure**: The teacher to provide students with materials, procedure and the diagram of a set up see Figure below that can be used to show that when the intensity of light increases, the rate of photosynthesis increases. The teacher asks the students to conduct the experiment using the procedure and record the results in a table such as Table 1.

   ![Diagram of photosynthesis experiment](image)

   **Figure 1: Set-up for investigating effect of light on photosynthesis**

<table>
<thead>
<tr>
<th>Distance of lamp from the water weed (cm)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bubbles of gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   **Answer**: Following the activity, the teacher leads the students in recognizing that when the distance between the lamp and the water weed decreases; light intensity increases and therefore more gas bubbles are produced per minute which means that the rate of photosynthesis increases with increase in the intensity of light.

   **b) Chemistry**
Let us consider an example in Chemistry using: Rate of reaction;

**Question:** What is the effect of surface area on the rate of reaction?

**Procedure:** The teacher provides students with materials, procedure and the diagram of a set up (see figure below) that can be used to show that when the surface area increases, the rate of reaction increases. The teacher may ask the students to conduct the experiment using the procedure and make observations in balloons.

![Powdered Calcium Carbonate](image1.jpg) ![Mable Chips (pellets of Calcium Carbonate)](image2.jpg)

**Set up for investigating the effect of surface area on the rate of reactions**

**Answer:** Following the activity, the teacher leads the students in recognizing that by increasing the surface area of a solid, we increase the number of reaction points with which a gas or liquid can react with. The rate of reaction increases with increase in the surface area of substance.

c) **Physics**

Let us consider an example in Physics using the example of verifying Hooke’s laws:

**Question:** What is the spring constant for the spring provided?

**Procedure:** Suspend different loads on the spring balance provided. Record the load and the extension of the spring. Plot a graph of the load against the extension.

**Answer:** Determine the slope of the graph. The slope is the spring constant.

d) **Mathematics**
Let us consider an example in Mathematics using an example of the expansion of quadratic expression:

**Question:** Expand \((a + b)^2\)

**Procedure:** The teacher may start by asking the students what \((a + b)^2\) will give when expanded. The idea of area of squares is used to confirm that \((a + b)^2 = a^2 + 2ab + b^2\)

The following steps are given to the learners to arrive at the above answer:

**Step 1:**
Find the length and the width of the figure given.
Find the area.
(Expected answer) \((a+b)^2\)

**Step 2:**
Find
- The area of each part and
- The total area.
(Expected answer) \(a^2 + 2ab + b^2\)

**Step 3:**
Compare the two expressions obtained in Step 1 and 2.
*Answer* \((a+b)^2 = a^2 + 2ab + b^2\)

Notice that in this kind of inquiry, students only conduct an activity to confirm the results of the investigation given by the teacher.

2. **Structured inquiry** - In this kind of inquiry, students are provided with questions, methods and materials and are challenged to discover relationships between given variables. The following are examples using content from biology, chemistry, mathematics and physics.

a) **Biology**

**Question:** How does light intensity affect the rate of photosynthesis in the water weed?

**Procedure:** The students are then told to collect a lamp, a beaker, and a twig of water weed and set up the experiment as shown in Figure 2. They are further asked to observe how many bubbles of gas come from the water weed each minute when the lamp is at 5, 10, 15, 20 and 25 cm away from the water weed and fill the results in a table such Table 1. The students are then left to examine the data and come to the realization that the rate of photosynthesis increase with an increase in light intensity.

b) **Chemistry**
**Question:** How does surface area affect the rate of reaction in the reaction between calcium carbonate and hydrochloric acid?

**Procedure:** The teacher provides students with materials, procedure and the diagram of a set up (see Figure 3). The teacher may ask the students to conduct the experiment using the procedure and make observations in balloons. They are further asked to observe how the size of the balloon is after some times.

c) **Physics**

**Question:** What is the spring constant for the spring provided?

**Procedure:** Suspend different loads on the spring balance provided. Record the load and the extension of the spring. Use the values of load and corresponding extension to determine the spring constant.

d) **Mathematics**

Using expansion of quadratic expression

**Question:** Expand \((a + b)^2\)

**Procedure:** Students are given a square and steps on how to get the area are given. Students are then asked to relate the area of the square to the expansion of \((a + b)^2\)

**Step 1:**
Find the length and the width of the figure given.
Find the area.
(Expected answer) \((a + b)^2\)

**Step 2:**
Find
- The area of each part and
- The total area.
(Expected answer) \(a^2 + 2ab + b^2\)

**Step 3**
What can you say about the expansion of \((a + b)^2\) and the area of the of the square you found.
Notice that in this kind of inquiry, the students are provided with information on how to proceed to answer the question and only left to examine the data for a relationship. In other words, unlike the case of confirmatory inquiry, the relationship between variables is not provided to the students.

3. **Guided inquiry** - In this kind of inquiry, students are provided with a question. However, the method for research is up to the students to develop. The following are examples using content from biology, chemistry, mathematics and physics.

a) **Biology**
**Question:** How does light intensity affect the rate of photosynthesis in the water weed?

**Procedure:**

**Answer:**

b) **Chemistry**

**Question:** How does surface area affect the rate of reaction in the reaction between calcium carbonate and hydrochloric acid?

**Procedure:**

**Answer:**

c) **Physics**

**Question:** What is the spring constant for the spring provided?

**Procedure:**

**Answer:**

d) **Mathematics**

Using expansion of quadratic expression

**Question:** Expand \((a + b)^2\)

**Procedure:**

**Answer:**

Notice that the students are guided on what to investigate. For example, in the case of biology, the students are directed to investigate the effect of a given factor (intensity of light) on the rate of photosynthesis. The procedure is left to them to design and use it to carry out the investigation.

4. **Open inquiry** - In this kind of inquiry, phenomena are proposed to students but students must develop their own questions and method for research to discover relationships among variables. The following are examples using content from biology, chemistry, mathematics and physics.

a) **Biology**
What are factors which affect the rate of photosynthesis in the water weed?

**Question:** ……………………………………………………………………………………………
**Procedure:** ……………………………………………………………………………………………
**Answer:** …………………………………………………………………………………………………

b) **Chemistry**
What are factors which affect the rate of reaction?

**Question:** ……………………………………………………………………………………………
**Procedure:** ……………………………………………………………………………………………
**Answer:** …………………………………………………………………………………………………

c) **Physics**
How to verify Hooke’s law

**Question:** ……………………………………………………………………………………………
**Procedure:** ……………………………………………………………………………………………
**Answer:** …………………………………………………………………………………………………

d) **Mathematics**
How to expand quadratic equations

**Question:** ……………………………………………………………………………………………
**Procedure:** ……………………………………………………………………………………………
**Answer:** …………………………………………………………………………………………………

Note that as the type of inquiry teaching changes from open through guided to structured, and finally confirmatory there is a gradual shift from student-centred to teacher centred teaching.

**Inquiry-based Activities in Mathematics and science**
Let us try out the following activities to have a hands-on experience on inquiry-based learning.

- **Mathematics: Inquiry about area using dots**

**Part 1:**
1. You are provided with a paper showing grids having the same number of dots.
2. Draw different polygons in each of the grids by joining dots. Make sure the polygon drawn encloses only one dot.
Part II:
1. Represent one of the polygons on the grid is shown below and calculate its area (assume that the dots are 1 unit apart vertically and horizontally)

Part III:
1. Display your polygon by sticking it on the wall using masking tape
2. Working with your peers, arrange the polygons in order of increasing area.
3. What do you notice about the number of dots joined and the area of the polygon?
4. Write your response in the space provided

---

- **Science: Inquiry using raisins and soda**
  1. What happens when soda is added to a gas jar containing pieces of raisins? (colourless soda such as sprite is recommended)
  2. How do you find out what happens?
  3. Implement your plan
  4. Explain the observations
In the space given, describe your plan including the diagram, state the observations and explain them.

.................................................................................................................................
.................................................................................................................................
.................................................................................................................................
What further questions does the activity help you to raise?
.................................................................................................................................
.................................................................................................................................
.................................................................................................................................

**The role of the Teacher in Inquiry-based Teaching and Learning**

The following are some of the roles a teacher may play during inquiry-based teaching and learning process. S/he:
- Assumes the role of a facilitator of the inquiry process
- Plans the various aspects of the lesson and guides learners in their investigations
- Ensures that learners are given ample time to conduct their investigations and go through the whole inquiry process
- Encourages learners to reflect on the various aspects of their investigations

**Benefits of Inquiry-based Learning**

The following are some of the benefits of inquiry-based learning.

Inquiry-based learning allows students to:
- Be more engaged with the subject. Learning is perceived as being more relevant to their own needs, thus they are enthusiastic and ready to learn.
- Expand on what they have learned by following their own research interests.
- Develop a more flexible approach to their studies that give them the freedom and responsibility to organize their own pattern of work within the time constraints of the task.
- Develop a variety of skills that include: hypothesizing, questioning, data collection and analysis, and inferring.
- Develop 21st Century skills such as collaboration, communication, teamwork, and problem-solving

**Identifying Aspects of Inquiry in a Lesson**

Now that you have some ideas about inquiry-based teaching and learning and how to enact teaching that embraces inquiry, you will now evaluate a lesson for aspects of the inquiry.

**Activity 1.3**

*Observe a lesson demonstration lesson and evaluate it for aspects of inquiry.*
In this section, you learned about the idea of inquiry-based learning and the need to create a culture in the classroom that allows students to engage in inquiry activities. It also provided a description of the process of inquiry-based in the classroom as well as examples of inquiry activities in mathematics and science to model inquiry-based learning. It is hoped that you found the experience invaluable and that you will be able to make every effort to ensure that inquiry-based learning experiences are incorporated into lessons. While it may not be easy to incorporate all the four types of inquiry in a lesson, it is important to incorporate at least one type of inquiry in a lesson and remember, we mentioned that as the type of inquiry teaching changes from confirmatory through structured to guided, and finally open there is a gradual shift in teaching from teacher-centered to student centered.

References
UNIT TWO: DEMONSTRATION LESSON

Introduction
Welcome to Unit two on lesson demonstration. Lesson demonstration was introduced to the implementation of Third Country Training Programme to give participants an opportunity to observe live lessons showcasing aspects of a good classroom practice. This year the process demonstration lesson will entail working with a teacher in preparing a lesson with elements of learner centred practices (ASEI–PDSI) and Inquiry Based Learning using the 5E instructional model. The lesson teachers’ school and a discussion training objectives. After the discussion by trainers at from the participants to reflect on

Rationale
A demonstration practices and lesson to be During the demo demonstrate concepts/strategies/ within the classroom. lesson enables concepts, processes of a good observed directly. lesson, teachers specific learning instructional models
This helps them improve their own teaching strategies including a change of perspective in relating to learners, more reflection in the teachers’ own classroom strategies, and more personal responsibility for student learning. It could also be aimed at giving participants/observers an opportunity to assess their knowledge and evolving understanding about classroom practice, enabling them to reinforce and clarify areas of strength as well as identify areas they need to grow including the skill for lesson observation and ability to collect evidence on student learning.

Goal
This unit will offer participants opportunity to observe a live IBL 5E instructional model lesson and participate in a post lesson discussion.

Learning Outcome
Participants gain skills in lesson observation and use the data to discuss the outcomes of a lesson.

Objectives
1. Give participants an overview of a good ASEI lesson based on Inquiry Based Learning using the 5E instructional model.
2. Provide a common experience for participants that will serve as the basis for discussing and developing good classroom practices in subsequent subject sessions.

**Panel Discussion**
A panel made of lecturers from CEMASTEA will discuss the lesson outcomes based on their observations. They will focus on preparation for the lesson, the content, and delivery and management of the lesson. Elements of good classroom practice with emphasis on teacher’s ability to bring out elements of learner centeredness and in particular IBL and the 5E instructional model. Panel chair will also open the discussion to the audience to point out areas of strength and those areas for improvement.
UNIT THREE: 5E INSTRUCTIONAL MODEL

Introduction
Welcome to Unit Three on the 5E instructional model. Having learnt about Inquiry Based Learning (IBL) and observed a demonstration lesson, we are now going to look into an instructional model that supports the appropriate implementation of the Inquiry Based Learning. In this unit we shall explore the 5E instructional Model. The 5E lesson has five stages that include; engagement, exploration, explanation, elaboration, and evaluation. We hope you will be able to use this model in planning and teaching your lessons.

Rationale
An instructional model, also called learning cycle, provides a teacher with a systematic approach through a sequence of stages that help learners develop a full understanding of a lesson concept. An instructional model is a scaffold that a teacher plans and develops prior to instruction to provide an effective and efficient learning experience. The 5E instructional model is one such model and has a specific function that is intended to contribute to the learning process. The model fits promote active instructional strategies such as demonstrations, discussions, questioning that are fundamental for effective learning.

Unit Goal: To build the capacity of participants to plan and implement a 5E lesson plan

Unit Objectives:
By the end of this unit, you shall be able to
1. Describe the stages of the 5E instructional model
2. Demonstrate the use of a 5E instructional model in lesson delivery.

Expected learning outcomes
By the end of the session, participants are able to plan and implement IBL lessons using the 5E instructional model.

Key Question for the Unit
How can the 5E Instructional Model be used to Stimulate Active, Collaborative, Inquiry-Based Learning?
Understanding the 5E Instructional Model

The 5E instructional model is based on the constructivist view of learning where learners construct core concepts (knowledge) through continuous interaction between themselves, the teacher and the environment. The constructivism strategy draws on learners existing knowledge, beliefs, and skills with learners synthesizing new understanding from prior learning/experiences and new information. The 5E model is suitable in an inquiry learning environment as the teacher presents learning experiences with problematic, challenging but achievable situations that are slightly beyond the current level of understanding of learners.

The 5E model is designed to facilitate learning with the teacher deliberately providing experiences that allow learners to experience learning through common activities (hands-on, minds-on scientific and mathematical inquiry) to build on prior knowledge and experience, construct meaning, and to assess their understanding of concepts continually. The teacher monitors learner’s exploration, guides their inquiry, and promotes new patterns of thinking in a systematic way.

So what is the meaning of a 5E instructional model?

This is a lesson planned on 5Es namely; engage (elicitation), explore, explain, elaboration (extend) and evaluate. We will now explain what each of this stages entails and the expectations for the teachers and learners

Reflection Question

What informs how you sequence activities in your lessons? Why?
- Objectives
- Skills and competencies to develop
- Expected learning outcomes
- Learners previous knowledge

The 5E Lesson Instruction Model

Engage
Requires purposive planning on how learners’ interest and curiosity will be aroused and sustained during the lesson. This can be through the use of models, skits, simulations, questions among other strategies some that draw on their previous knowledge. It helps to focus learners on the main ideas of the lesson. Anticipate activities and focus learners’ thinking on the learning outcomes of current activities. During engagement learners should become mentally engaged in the concept, process, or skill to be learned.
Explore
During exploration opportunities should be provided for learners to manipulate, investigate or critically analyze and discuss a phenomenon in order to help them construct new knowledge or learn. Learners are encouraged to apply science process skills, such as observing, questioning, investigating, testing predictions, hypothesizing, and communicating, with other peers.

Explain
While exploring learners make observations and inferences which they now must give meaning to through explanations. Explanations enable learner thinking to be observed and relevant remediation is given to address misconceptions. They have opportunities to verbalize their conceptual understanding or to demonstrate new skills or behaviors. This phase also provides opportunities for teachers to introduce formal terms, definitions, and explanations for concepts, processes, skills, or behaviors.

Elaboration/Extend
The extension part of the lesson involves giving learners a different but related situations for them to apply ideas learned to a new situation. It also entails explaining in more details to enhance clarity. At this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them in new ways. i.e. This phase of the 5 E's extends students' conceptual understanding and allows them to practice skills and behaviors. Through new experiences, the learners develop deeper and broader understanding of major concepts, obtain more information about areas of interest, and refine their skills.

Evaluate
The evaluation is of two kinds, Learners may evaluate their work or output as well as the teacher by finding out if learning has taken place in relation to the lesson objectives. It allows the teacher to determine if the learner has attained an understanding of concepts and knowledge. Evaluation can occur at all stages of the instructional process.

Why the 5E lesson model
- Enhances learner understanding and achievement
- Enhances teacher classroom behavior
- Enhances science process skills
- Connects concepts to real life situations

Sample 5E lesson plan
The lesson below was planned based on the 5E format described above.
LESSON PLAN ON TRANSPORT IN PLANTS

CLASS: Form 2
SUBTOPIC: Factors affecting transpiration

OBJECTIVE: Determine the relationship between number of stomata and the rate of transpiration

RATIONALE: There are several factors that affect the rate at which plants lose water into the atmosphere. These factors are classified as environmental and structural. The number of stomata on a plant is one of the structural factors. In this lesson you are going to investigate how the number of stomata affects the rate of transpiration in a plant.

TARGET SKILLS:
- Measurement and data recording
- Observation
- Inference
- Analysis
- Collaboration
- Communication

Scientific attitudes and noble values: Interest, curiosity, honesty, responsibility and appreciation

LEARNING OUTCOME:

Learners are expected to learn that plants lose most water through the Stomata and therefore the number, the size of stomata and location of Stomata determine the amount of water lost. They will also appreciate how transpiration contributes to environmental precipitation.


MATERIALS: Hot water, (between 80- 85°C), two types of leaves, beakers and thermometers.
<table>
<thead>
<tr>
<th>Time</th>
<th>Teacher’s activity</th>
<th>Learners’ activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Teacher introduces the lesson by asking the learners the following questions:</td>
<td>Learners answering</td>
</tr>
<tr>
<td>5 minutes</td>
<td>• What is transpiration?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Teachers ask learners to identify the two leaves.</td>
<td></td>
</tr>
<tr>
<td>ENGAGEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson Development 1</td>
<td>• Which of the two leaves do you think will lose more water to the atmosphere and why?</td>
<td>Making predictions</td>
</tr>
<tr>
<td>ENGAGEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesson development 2</td>
<td>In this activity we will investigate the relationship between number of stomata and rate of transpiration.</td>
<td>Carry out investigations</td>
</tr>
<tr>
<td>EXPLORATION</td>
<td>Teacher hands over worksheet 1 to the learners to carry out the activity. Teacher guides the learners through discussion of questions on worksheet 1</td>
<td></td>
</tr>
<tr>
<td>Lesson Development 3</td>
<td>Teacher gives learners 5 minutes to brainstorm and then present their ideas to the rest for critiquing and improvement.</td>
<td>Explain their findings from</td>
</tr>
<tr>
<td>EXPLANATION</td>
<td></td>
<td>the investigation</td>
</tr>
<tr>
<td>Lesson development 4</td>
<td>The teacher provides the scenario below (worksheet 2):</td>
<td>Brainstorming</td>
</tr>
<tr>
<td>EXTENSION'</td>
<td>• In the early 2000’s Kenya started experiencing less rainfall annually. The government instructed farmers to plant more eucalyptus trees on their farms. Why do you think eucalyptus was chosen based on the previous experiment?</td>
<td>Learners pair up and discuss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>activity</td>
</tr>
<tr>
<td></td>
<td>Teacher gives learners 5 minutes to brainstorm then present their ideas to the class for harmonization</td>
<td>Learners answering</td>
</tr>
<tr>
<td>Evaluation and conclusion</td>
<td>Why is transpiration important?</td>
<td>Give answers</td>
</tr>
<tr>
<td>(5 minutes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVALUATION</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WORKSHEET 1**

**AIM:** To investigate the relationship between the number of stomata and water loss.

**MATERIALS:** Hot water, forceps, plastic jug, petri dishes, leaves labelled A and B.

**PROCEDURE:**
- Pour about 500ml of hot water into the beaker.
- Drop both leaves in hot water with the upper surface facing down.
- Compare and record the number of air bubbles formed on the lower surface of the leaves on the table below.
Table

<table>
<thead>
<tr>
<th>Type of leaf</th>
<th>Leaf A</th>
<th>Leaf B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bubbles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Identify leaf A and B
   Leaf A...........................................................
   Leaf B...........................................................

2. From which structures are the bubbles coming from?
   ...............................................................................................................................

3. Which leaf has the most number of stomata?
   ........................................................................................................................................

4. What conclusion would you draw from your results on the table?
   ........................................................................................................................................

WORKSHEET 2

In the year 2000, Kenya started experiencing less rainfall annually. The government instructed farmers to plant more eucalyptus trees on their farms. Why do you think eucalyptus was chosen based on the previous experiment?

References

https://primaryconnections.org.au/about/teaching (20th June 2017)
UNIT FOUR: SUBJECT BASED SESSIONS

Introduction
This unit is a continuation of unit one and three where dealt with the basics of Inquiry Based Learning (IBL) and the 5E instructional model for teaching. You will get the opportunity to apply the principles learnt in unit one to four subject areas that include biology, chemistry physics and mathematics. In each of the subjects, we will use two subject-based topics to further explore IBL and the practice of the 5E instructional model. The topics have structured tasks involving reflection on participant’s experience in the learning of these topics, group discussions, hands-on activities and designing of activities/experiments that can use to demonstrate the application and use Inquiry Based Learning (IBL) in science and mathematics. Participants will also discuss a 5E lesson in each of the topics and an assessment component accompanying the same. Finally in each of the topics you will develop a lesson plan using the 5E instructional model.

BIOLOGY

Topic One: Nutrition in Plants and Animals

Introduction
In this section we will use the topic Nutrition in plants and animals to illustrate inquiry based learning using the 5E instructional model in Biology. The section is divided into three sub-sections. Sub-section one consists of preliminaries which include rationale, goal, objectives, and outcomes. Sub-section two consists of inquiry based learning activities using 5 E, and in sub-sections three you will lesson plan and peer teaches an ASEI lesson that incorporates Inquiry Based Learning using the 5E instructional model.

Rationale
Nutrition is one of the characteristics of all living things. It is the scientific study of nutrients in the food and how the body cells use the different type of nutrients. Nutrition is a topic that is applicable to everyday life and it is therefore important that learners understand the role of different nutrients in the body. It is also very important for learners to understand the relationship between plant and animal nutrition. Teachers should be able to make use of Inquiry based learning and the 5E model of instruction to enable learners to understand the concept in nutrition.

Goal
To enhance your ability to incorporate Inquiry Based Learning using the 5E instructional model in teaching biology.
Session objectives
1. Design and carry out activities that incorporate inquiry-based learning using the 5E instructional model in the topic nutrition
2. Develop an ASEI lesson that incorporates inquiry-based learning using the 5E instructional Model
3. Appreciate the importance of Inquiry Based Learning using the 5E instructional model

Learning outcome
You should be able to plan and teach a 5E Instructional model on Inquiry Based biology lesson

Activity 1: How can you investigate the process of digestion?

Materials:
- Suspension of substance X
- diastase
- Iodine solution
- Beaker
- Water
- Thermometer
- Pipette
- Means of heating
- White tile
- Timer
- 2 Test tubes labelled as A and B

Procedure
1. In test tube A add 2 cm$^3$ of suspension X
2. In test tube B, add 2 cm$^3$ of suspension X and 1 cm$^3$ of diastase into a test tube respectively
3. Using the pipette place 3 drops of the mixture in test tube B on a white tile.
4. Add one drop of iodine to the mixture on the white tile. Record your observation on the table below.
5. Using a clean pipette place 3 drops of suspension X on a white tile
6. Add one drop of iodine to the suspension X on a white tile. Record your observation
7. Place the test tubes A and B in step 1 in a water bath (37$^0$C) for 5 minutes.
8. Using a pipette place another 3 drops of each content from A and B on a white tile and add a drop of iodine on each of the content, and record your observations in the table below.
9. Repeat after 10 minutes and make your observation and record on the table below
1. With reason identify substance X?
2. Why was the temperature maintained at 37°C?
3. What happened to substance x as time progressed from A and B
4. How is this experiment similar to digestion of bread in man?

<table>
<thead>
<tr>
<th>Time</th>
<th>0 minute</th>
<th>5 minutes</th>
<th>10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Tube</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Observation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explanation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How is the above experiment similar to digestion of bread by man?

With reason name the type of Inquiry Based Learning represented by activity 1?

Does digestion take place in plants?
Activity 2: Is there a difference in food composition between dry seeds and germinating seeds?

**Activity 2:** Let us now investigate the composition of food in dry seeds and germinating seeds. Use the materials provided to carry out tests for starch and reducing sugar in dry and germinating seeds.

**Materials provided**
- Mortar and pestle
- Dry seeds
- Germinating seeds
- Test tubes
- Test-tube rack
- Benedict's solution
- Stirring rod
- Plastic gloves
- Test-tube holder
- Iodine solution
- Distilled water
- Dropper

**Procedure**

**Test for starch**
1. Cut a cross section of both the dry and the germinating seed
2. Place a drop of iodine in the cotyledon/endosperm and observe

**Procedure for testing for reducing sugar**
1. Grind the dry and the germinating seeds separately to make two suspensions
2. Put 2 cm³ of the solution/suspension to be tested into separate test tubes
3. Label the test tubes with the solutions with the solutions in them
4. To each test tube, add 2 cm³ of Benedict’s solution
5. Boil for about two minutes and observe as it cools

<table>
<thead>
<tr>
<th>Type of Food Test</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed</td>
<td>Dry Seed</td>
</tr>
<tr>
<td>Starch</td>
<td></td>
</tr>
<tr>
<td>Reducing sugar</td>
<td></td>
</tr>
</tbody>
</table>

Account for the difference in food components?
Activity 3: Effect of light on photosynthesis

Does light have any effect on photosynthesis?

Activity 3: How can you investigate this?
1. State your hypothesis for the investigation.
2. Design how you would investigate effect of light on photosynthesis
   a. List the materials you will need
   b. Draw your set up
   c. Predict your expected observations

Activity 4: ASEI-PDSI lesson

In this activity you will critique the ASEI lesson provided in light of inquiry Based learning and 5E instructional model

Class: Form 1

Topic: Nutrition in Plants

Sub topic: Enzymatic activity in breakdown of food

Rationale: The process of digestion is normally associated with animals. In plants photosynthesis is discussed in nutrition but learners are not able to link what happens to stored food in plants during germination to enzymatic digestion of food. It is important for learners to understand that breakdown of food is an enzymatic reaction and that diastase occurs in plants and amylase in animals.

Objectives: By the end of the lesson learner will be able to:
1. Identify the food composition in dry seeds and germinating seeds
2. Explain the relationship between seed germination and digestion

Target skills
- Experimental design
- Observation
- Analysis
- Measurement and data recording
Learning outcome
Learners are expected to understand the process of germination as a form of digestion in relation to enzymatic activities

References
1. KLB biology Book 1,(2004) Transport in Plants, Nairobi

Materials provided
- Mortar and pestle
- Dry seeds
- Germinating seeds
- Test tubes
- Test-tube rack
- Benedict’s solution
- Stirring rod
- Plastic gloves
- Test-tube holder
- Iodine solution
- Distilled water
- Droppers

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TEACHER ACTIVITY</th>
<th>LEARNERS ACTIVITY</th>
<th>LEARNING POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Ask learners “plants make their own food during photosynthesis.</td>
<td>Learners pair and share on where plants store their food and in which form is the food stored</td>
<td>Plants store food in the seed, stem and root.</td>
</tr>
<tr>
<td>(Engage)</td>
<td>• Where is this food stored?</td>
<td></td>
<td>Form of food stored is starch, proteins and oils</td>
</tr>
<tr>
<td>(5 minutes)</td>
<td>• in what form is this food stored?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Development | You are now going to investigate the composition of food in dry seeds and germinating seeds.  
Step 1   | Teacher Distributes the activity sheet to each group, introduce the materials and guide pupils on how to carry out the activity | Learners in their groups carry out the test for starch and reducing sugar in dry seeds and in germinating seeds And fill in their finding on the table provided in the student’s worksheet | Dry seeds stores food in the form of starch when water is available the enzymatic reaction starts to break down the stored complex food into simple foods that can be utilized by the embryo to grow into a seedling The embryo inside the seed uses the food and grows its first leaves |
**Learner’s work sheet**

**PROCEDURE**

**Test for starch**
Cut a cross section of both the dry and the germinating seed place a drop of iodine in the cotyledon/endosperm and observe

**Procedure for testing for reducing sugar**
1. Grind the dry and the germinating seed separately and water to make two suspensions
2. Put 2 cm$^3$ of the solution/suspension to be tested into separate test tubes
3. Label the test tubes with the solutions with the solutions in them
4. To each test tube, add 2 cm$^3$ of Benedict’s solution
5. Boil for about two minutes and observe as it cools

<table>
<thead>
<tr>
<th>Type of Food Test</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed</td>
<td>Dry Seed</td>
</tr>
<tr>
<td>Starch</td>
<td></td>
</tr>
<tr>
<td>Reducing sugar</td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td></td>
</tr>
</tbody>
</table>

**Lesson evaluation question**

A student set up an experiment to investigate a certain physiological process as shown below.

![Diagram](image)

After 24 hours the student flooded the petri dishes with iodine solution. It was observed that seeds in petri dish A had a brown colour surrounding the seeds while the rest of the agar was blue black. In Petri dish B all agar was blue black.

Account for the observations in A and B

<table>
<thead>
<tr>
<th>Petri dish A</th>
<th>Petri dish B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Critique of sample IBL 5E lesson plan: Indicators of an IBL classroom

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Evidence</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learners are engaged in an inquiry based question or task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Engagement)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners respond to questions with evidence or carry out activities with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to gather evidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Exploration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners formulate explanations from evidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Explanation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners communicate and justify explanations based on investigations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(application/elaboration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners assess understanding, demonstrates understanding of the new</td>
<td></td>
<td></td>
</tr>
<tr>
<td>concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Evaluation)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Activity 5: IBL Lesson Planning

**Activity 5:**
Identify a concept from the areas in the topic Nutrition in plants and animals and develop an ASEI lesson that incorporates inquiry based learning strategy using 5E instructional model.
Select one of the group members to peer teach as others observe and critique

Conclusion
In this section of the unit you have practiced using the 5 E instructional models on IBL approach in teaching biology with examples from the topic of nutrition. It is our hope that the skills, knowledge, and attitudes you have gained will translate into effective classroom delivery and apply the same to other topics in the subject

References
Topic Two: Respiration

Introduction
Welcome to this section of the module. In this section, we are going to use the topic respiration to demonstrate how you can plan and implement inquiry based learning experiences for your learners. This section is divided into two: sub-section one is the preliminaries which consist of rationale, objectives, and learning outcomes. Sub-section two consists of teaching and learning activities as well as lesson planning and peer teaching.

Rationale
Many learners and even some teachers confuse respiration and gaseous exchange. However, the two are very distinct. They occur continuously in a sequential manner. The gaseous exchange involves the moving in of air and out of the lungs, while respiration takes place at the cellular level to release energy. When this does not come out clearly it leads to misconceptions and misunderstandings of the biological concepts/physiological processes that build from this stage. Therefore, learners should be guided to inquire into this topic so that they carry out activities to investigate concepts in topic respiration.

Goal
To enhance your ability to use inquiry based learning in Biology and to enhance the use of the 5-E model lesson plan

Session Objectives:
By the end of this session, you should be able to;
1. Develop and use inquiry based learning activities on respiration
2. Develop a 5-E instructional lesson plan model based on ASEI lesson
3. Observe and evaluate an inquiry based lesson the 5-E instructional model

Learning outcomes
Participants demonstrate the ability to plan and implement IBL in the teaching and learning of biology.

Respiration
In this section you are going to carry out inquiry based learning activities and also plan a 5-E lesson plan on this topic

Activity 1
a) What are the respiratory products in living organisms
b) differentiate between gaseous exchange and respiration
You may have come up with the following responses:

- Carbon dioxide
- Lactic acid
- Water
- Nitrogenous wastes
- Urea
- Uric acid

**The differences between gaseous exchange and respiration**

Some of the differences you could have come with could be:

- Breathing is taking of air in and out of the lungs
- Gaseous exchange is the intake of oxygen and the excretion of carbon dioxide at the lung surface
- Oxygen moves into the blood and carbon dioxide moves out of the blood
- Cell respiration is the process that releases energy from the food

**Activity 2**

Using the materials and apparatus provided, explore the various products of respiration in the living organisms

- Leafy Geranium shoots
- Small animals (ants)
- Large plastic bottle (with cork) / black polythene bags
- Plastic tubing / Delivery tubes
- Small specimen bottle
- Thin Cotton thread
- Beaker
- Lime water/ Calcium Hydroxide
- Pyrogallic acid/ wooden splint
- Black piece of cloth
- Rubber bands

**Reflection**

With reason name the type of Inquiry Based Learning represented by activity 2?
Materials and apparatus
- Thermometers, cotton wool, aluminum foil, soaked bean seeds, dry bean seeds
- Plasticine, plastic cans with covers (250gm), clamps, thick cotton thread, dilute disinfectant (jik), cork borer, vacuum flasks

Procedure:
Use the materials provided to set up an experiment to demonstrate heat production by germinating seeds

a) (i) Using plastic can
(ii) Using vacuum flask
b) Compare the results from the two setups and comment
c) Draw the experimental set up.
d) In case the school has no money to buy plasticine and aluminum foil what improvised materials from the surrounding would you use as a substitute in this experiment?
e) Suggest a suitable control for this experiment.

Reflection
With reason name the type of Inquiry Based Learning represented by activity 3?

Activity 4
Explain how you would demonstrate anaerobic respiration by yeast using the materials and apparatus provided

Materials and apparatus:
- Boiling tubes, conical flasks with corks (with hole in center), glucose, baker’s yeast, liquid paraffin oil, lime water
- Delivery tubes, Glass rod, thermometer, measuring cylinder, spatula, Bunsen burner, tripod stand
**Procedure:**
1) Boil some 10ml of water in a conical flask and then dissolve 5 spatulae of glucose in it. Leave it to cool to about 30°C and then add 20ml yeast suspension and stir.
2) Add liquid 20ml of paraffin using a pipette by gently pouring it down the side of the flask.
3) Set up the rest of the apparatus so as to investigate the production of carbon dioxide by yeast respiration.
4) In what other ways could this setup be used?
5) Account for the observations made in the experiment.

*Set up to show carbon dioxide production by anaerobic respiration of yeast*

**Materials and apparatus:**
- Groundnuts, maize (dry) grains, beans (dry) seeds, castor
- Mounted needles, thermometers, boiling tube, Bunsen burner & lighter, clamp, electronic balance wooden splints
- Distilled water
Procedure:

a) Measure 10cm³ distilled water in a boiling tube.
b) Measure the initial temperature (T₁) and record.
c) Carefully weigh a piece of each of the food substances provided and record their weights (in grams).
d) Fix the food substance on the tip of a mounted needle.
e) Ignite the food and once it starts burning place it under the boiling tube containing water and continues to stir the water.
f) When the food is completely burned record the final temperature of water (T₂°C).

![Diagram of setup](image)

*Set up showing that peanuts release energy when they are oxidised*

<table>
<thead>
<tr>
<th>Food substance</th>
<th>Weight of food (gm)</th>
<th>Initial Temperature of water</th>
<th>Final Temperature of water</th>
<th>Temperature Change(°C)</th>
<th>Energy produced by 1 gm of food</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Groundnut</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Bean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Castor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Calculate the amount of energy produced by 1 gram of each of the food substances and compare their energy values. To do this, you need to know the following:

Mass of 10 cm$^3$ water = 10gms (1 cm$^3$ water weigh 1gm)

4200 J raises the temp. of 1 gm of water by 1$^\circ$C (Specific Heat Capacity of water)

The increase in temp. of water = $T_2 - T_1$°C

Energy in 1 gm peanut = $4200 \times (T_2 - T_1 °C) \text{ J g}^{-1}$

Which food is more appropriate for the following categories of people and state reasons?

<table>
<thead>
<tr>
<th>S/No.</th>
<th>Category of people</th>
<th>Type of food</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Adult men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Adolescent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Pregnant women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Children</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

g) The amount of heat energy calculated above is less than the expected. Explain this observation.

With reason name the type of Inquiry Based Learning represented by activity 5?
Activity 6: ASEI-PDSI lesson
In this activity you will critique the ASEI lesson provided in light of inquiry Based learning and 5E instructional model

TOPIC: Respiration
SUBTOPIC: Respiratory Substrates
Lesson Objective: By the end of the lesson the learner should be able to:
1. Understand that food substances produce energy when oxidized,
2. Appreciate that Different food substances produce different amounts of energy when oxidized
PRE-REQUISITE KNOWLEDGE: Gaseous exchange mechanisms, Types of respiration, transport of gases in plants and animals, differences between anaerobic and aerobic respiration.

TEACHING & LEARNING MATERIALS:
Boiling tubes, Conical flasks with corks (with hole in center), Glucose, Baker’s Yeast, Liquid paraffin oil, Delivery tubes, Lime water, Glass rod, Thermometer, Measuring cylinder, Spatula, Bunsen burner, Tripod stand

REFERENCES:
KIE (1999), Secondary Biology and Biological Sciences, Pupils’ Book Two, (2nd Ed.)
Kenya Literature Bureau, Nairobi

<table>
<thead>
<tr>
<th>Lesson Development stages</th>
<th>Teacher Activity</th>
<th>Learning Activity</th>
<th>Learning Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>Identify and discuss who amongst the following would require more energy?</td>
<td>Learners think pair and share and give their answers</td>
<td>Manual work-more (groundnuts) since uses more energy in laborious work</td>
</tr>
<tr>
<td>Engagement</td>
<td>1.Manual worker</td>
<td></td>
<td>Office worker: mainly sedentary work hence most energy not dispensed by the body</td>
</tr>
<tr>
<td>(5 Minutes)</td>
<td>2.Teacher</td>
<td></td>
<td>Teachers: Does a lot of talking and walking while doing work</td>
</tr>
<tr>
<td></td>
<td>3.Office worker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td>Exploration (10 Minutes)</td>
<td>Explanation (10 Minutes)</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>Step 1</td>
<td>Given maize grain, groundnuts and beans, predict which of these would give more energy when burnt?</td>
<td>Learners predict the food that has more energy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teacher provides materials to learners and guides them on how to determine the amount of energy in the specified food substances provided as per the worksheet</td>
<td>Students follow the procedure in the worksheet and investigate the amount of energy in each provided food substance</td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td>Teacher asks learners to explain the differences in the amounts of energy produced by groundnuts, maize and beans</td>
<td>Students observe what happens to the food substance as it burns and record the changes in temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Learners discuss the reasons why there are differences in the amount of energy in the tree food substances</td>
<td>Students calculate the amount of energy produced when a unit mass of the food substance is burnt.</td>
<td></td>
</tr>
</tbody>
</table>

Groundnuts contain a higher percentage of lipids and starch which produce high energy.

Maize has mainly high percentage of starch with very minimal oil therefore produces

Beans have a low percentage of starch.

Thus groundnuts would be recommended for people engaged in manual work

Groundnuts are more expensive than maize hence people engaged in manual work can readily afford groundnuts.
Elaboration
/Extension
Though it has been observed that groundnuts release more energy, it is observed that people doing manual work feed more on maize than groundnuts. Discuss this observation.

Students research and discuss and share their findings and record •

Evaluation
5 Minutes
Which of the three food substances would be recommended for people working in a construction site?

Learners to do a small literature search on the internet to give a brief explanation

Groundnuts have more oil in addition to starch hence more heat

Conclusion
5 Minutes
Teacher asks learners what they have learnt

Individual learners give what they have learnt

Food substances produce different amounts of energy when oxidized

Assessment

A student set up an experiment using soaked and dry seeds as shown below

Use the set up to answer the questions below

a. State the objectives of this experiment and the observations made after 24 hours.
b. Account for the observations made in (a) above
c. Suggest why vacuum flask was used in the experiment
d. What alteration would you make in the set-up to make the results more reliable

### Critique of sample IBL 5E lesson plan: Indicators of an IBL classroom

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Evidence</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learners are engaged in an inquiry based question or task (Engagement)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners respond to questions with evidence or carry out activities with to gather evidence (Exploration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners formulate explanations from evidence (Explanation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners communicate and justify explanations based on investigations (application/elaboration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learners assess understanding, demonstrates understanding of the new concept (Evaluation)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Activity 7: IBL Lesson Planning

Activity 7:

Identify a concept from the areas in the topic Respiration and develop an ASEI lesson that incorporates inquiry based learning strategy using 5E instructional model.

**NB:** You will present the lesson developed through peer teaching for 20 minutes where your colleagues will critique. You will then use the feedback to improve the lesson. This lesson will be used for practical teaching in schools.

### Conclusion

Though an understanding of the concepts and skills in this topic of respiration is important, our interest is that lessons learnt during the session lay a foundation for further inquiry in the use of IBL and 5E instructional model in the teaching of biology. You will therefore need to continue being innovative in developing teaching and learning activities that are inquiry based to help learners enjoy, understand and master the concepts better.
References:


2. KIE (1999), *Secondary Biology and Biological Sciences*, Pupils’ Book Two, (2nd Ed.) Kenya Literature Bureau, Nairobi


CHEMISTRY

Introduction
In this section we will explore ways of implementing inquiry-based learning in chemistry using two topics: *Salts* and *Topic two structure and bonding*. However, the skills learnt can apply in the teaching and learning of any other topics in Chemistry.

Topic One: Salts

Introduction
Welcome to this session in which we will explore ways of enhancing inquiry-based learning in Chemistry using the topic *Salts*. The session aims at enhancing your skills to use in inquiry-based learning (IBL) in order to help learners understand concepts in this topic.

Rationale
Salts are very useful in all fields ranging from fertilizers in agriculture to management of health by use of anti-acid drugs to treat stomach upsets. The usefulness of salts cannot be overstated, as additives in our food, licks to livestock to other domestic applications. The topic on acids and bases poses many challenges to students of various backgrounds. Further, Burns (1982) asserts that the topic has been reported to be difficult for high school students. The inclusion of this session in the module aims at enhancing your ability in Inquiry Based learning (IBL) and use of the 5E instructional model in teaching and learning of this topic.

Unit goal
To promote IBL through activities developed in salts based on 5E instructional model
Unit outcome
Demonstrate ability to integrate IBL in ASEI lesson using the 5E instructional model

Unit Objectives
By the end of the session you should be able to:

1. Design and carry out activities that enhance IBL in the teaching and learning of topic salts
2. Develop an ASEI lesson that integrates IBL using 5E instructional model. Enhance your ability to design innovative teaching and learning activities using IBL skills.
3. Evaluate the level of IBL in the ASEI lesson plan based on 5E model.
4. Appreciate the importance of IBL approach using 5E instructional model in teaching Salts.

Content in salts
Salts is a topic in high school in many countries in Africa. In this topic learners are expected to gain knowledge of different methods of preparing salts, use correct technical terms in the topic, state types of salts, identify soluble and insoluble salts and describe experimental observations on the action of heat on salts and state uses of some salts. We are going to explore activities in the various levels of IBL using 5E instructional model.

Teaching and learning activities in the Topic Salts
Activity 1: Reflection
You are now going to be given an opportunity to reflect and carry out activities which promote the teaching and learning of inquiry based learning.

Reflection

Based on the general session discussion, share your country experiences in using
a. IBL in teaching and learning in chemistry
b. 5E instructional model in teaching and learning chemistry

Activity 2
In this activity we are going to investigate which of the provided substances is a nitrate. All nitrates are soluble in water.

You are provided with two salts A and B. Which of the two salts A and B is a nitrate?
Procedure
i. Place a spatula end full of An in a test tube
ii. Add a little water while shaking the test tube
iii. Record your observation
iv. Repeat procedure (i) to (iii) using substance B in place of A

Discussion questions
a. Which of the two substances is a Nitrate?
b.

2. What level of IBL is this activity? Explain

Activity 3
Salt B is Sulphate. Are all Sulphates insoluble in water?
Materials: Potassium sulphate, Ammonium sulphate, Barium sulphate, Lead sulphate

Procedure
i. Place a spatula end full of potassium sulphate in a test tube
ii. Add a 5ml water while shaking the test tube
iii. Record your observation
iv. Repeat procedure (i) to (iii) using the sulphates of ammonium, barium and lead respectively

Record your observations in the table below.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Soluble</th>
<th>Insoluble</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Potassium sulphate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Ammonium sulphate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Barium sulphate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Lead sulphate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion
1. Which salts dissolved in water?

2. Which salts did not dissolve in water?
What conclusion can you make about the solubility of sulphates in water?

**Activity 4. Solubility of carbonates and chlorides**
You are provided with the carbonates and chlorides: potassium carbonate, calcium carbonate, sodium hydrogen carbonate, zinc carbonate, copper II carbonate

Zinc chloride, Magnesium chloride, Lead chloride, Sodium chloride, barium chloride

Design an experiment to determine the solubility of carbonates and chlorides in water.

**Activity 5**
Farmers in *Ngongo* location are facing a problem of excess acid in the soil, how would you advise the farmers to reduce the levels of acidity in the soil.

**Activity 6**

---

**a) Critique the sample ASEI lesson plan that integrates IBL using 5E instructional model. Identify Strengths and suggest areas for improvement.**

---

**SAMPLE LESSON**

**TOPIC:** Salts

**SUB-TOPIC:** Preparation of insoluble salts

**LEVEL:** FORM 2

**Time:** 40 Min

**Rationale**
Salts play a very important role in human life that ranges from body systems to application such as fertilizers in farming. All salts are ionic compounds made up of two ions – a positive ion that is either metallic ion or ammonium ion and a negative ion that comes from an acid. The method used to prepare salts depends on whether the salt is soluble or insoluble. In this lesson we will investigate preparation of insoluble salts of lead and also explore how the knowledge and skills learnt can be applied in real world.

**Objectives**
By the end of the lesson, the learner should be able to:

1. Prepare an insoluble salt
2. Apply knowledge and skill learnt to solve real life problems.

**Prerequisite knowledge**
Learners should have basic knowledge of common salts.
**Materials**
Beakers, filter papers, filter funnel, assorted salts that include common salt, Lead (II) nitrate, potassium iodide, etc.

**References**
KLB (2016), Chemistry Form 2 students” Book, 4th Edition

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TEACHERS ACTIVITY</th>
<th>LEARNERS ACTIVITY</th>
<th>LEARNING POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction (ENGAGE) (5min)</td>
<td><strong>Engage</strong> Show learners sample salts (common salts and CaCO₃) <em>What are the similarities and differences in the samples?</em></td>
<td>Observe appearance Think-pair-share to compare notes</td>
<td>The samples are SALTS. Same colour Different texture.</td>
</tr>
<tr>
<td>Development Step 10 min (Engage)</td>
<td>Put sample salts (NaCl and CaCO₃) in separate test tubes and add water. <em>Q. Ask students How they can separate a solid mixture of the two salts</em></td>
<td>Note observations learners reflect on how the mixtures may be separated</td>
<td>one of the salts is soluble and the other one is insoluble. Separation may be through filtration</td>
</tr>
<tr>
<td>Step 2 (10 min) (Exploration)</td>
<td>Ask students to put lead (II) nitrate solution into test tubes A and B. Into test tube A add KI solution drop wise until test tube is half–full of mixture Into test tube B add Na₂SO₄ solution instead of KI Filter and run water through the residue before drying it. <em>Why is it necessary to wash the residue?</em></td>
<td>Note the observation Note formation of precipitate Reflect on why it is necessary to wash the residue</td>
<td>Yellow precipitate and white precipitate formed Mixture be separated by filtration Rationale for washing residue after filtration Lead iodide is insoluble Lead sulphate is insoluble</td>
</tr>
<tr>
<td>Step 3 - 10 min (Explanation)</td>
<td>Explain the changes observed <em>Use equation to explain your results</em></td>
<td>Learner discuss and explain possible reactions based on their findings</td>
<td>Soluble salts react to form insoluble salts Method of preparation known as precipitation or double decomposition [ \text{Pb}^{2+}(<em>{\text{aq}}) + 2\text{I}^-(</em>{\text{aq}}) = \text{PbI}<em>2(</em>{\text{s}}) ] Writing ionic equation</td>
</tr>
<tr>
<td>Step 3 10min Elaboration (Application)</td>
<td>Plaster of Paris is used in hospitals to manage fractures.</td>
<td>Learner brain storm and report their findings</td>
<td>Apply knowledge of precipitation to solve problems in real life.</td>
</tr>
</tbody>
</table>
**Project Work / Home Work**
Learners are given a scenario of an informal industry dealing with car batteries resulting lead ions seepage into a stream that provides water meant for domestic use and irrigation. *They are told that Lead ions are harmful to life. Ask them to make use the knowledge learnt in the lesson to design a project they may use to make the water safe?*

**Evaluation item**
How you would prepare a sample of lead (II) sulphate starting from Lead (II) oxide. Explain the reaction that takes place in each stage using balanced chemical equation.

---

| Step 4 (Evaluation) | Ask learners to brainstorm on how they can prepare a sample of CaSO₄ in the Lab | Assess understanding of concepts based on group reports | Reaction given to involve Calcium ions and sulphate ions

Ca²⁺(aq) + SO₄²⁻(aq) = CaSO₄(s) |

| Conclusion (5 min) (Evaluation) | The teacher uses learners’ idea to consolidate key points. Teacher asks questions to check understanding. | Learners participate in conclusion

Learners respond to questions posed | Insoluble salts prepared by precipitation/double decomposition |
STUDENTS’ WORKSHEET

1. You are provided with sample solids A (Calcium carbonate) B (Sodium chloride)

What are the similarities and differences in the two samples?

---------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------

2. Put sample salts provided (NaCl and CaCO₃) in separate test tubes and add water. Note the observation.

---------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------

How can we separate a solid mixture of NaCl and CaCO₃?

---------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------

3. Put lead (II) nitrate solution in two test tubes labeled X and Y. Into test tube X, add KI solution drop wise until test tube is half–full of mixture.

Repeat the process by using sodium carbonate solution instead of KI. Filter to collect the residue. Run water through the residue before drying it.

i. What do you observe?

---------------------------------------------------------------------------------------------------

ii. Explain the observation.

---------------------------------------------------------------------------------------------------

iii. Write an equation for the reaction.

---------------------------------------------------------------------------------------------------

iv. Why is it necessary to wash the residue?

---------------------------------------------------------------------------------------------------

4. Plaster of Paris that is used in hospitals to treat bone fractures resulting from accidents is made of CaSO₄.

How would you prepare a sample of CaSO₄ in the laboratory?
5. How you would prepare a sample of lead (II) sulphate starting from Lead (II) oxide. Explain the reaction that takes place in each stage using balanced chemical equation.

Project Work
A small industry is dealing with car batteries that result into lead ions seepage into a stream that provides water for home use and irrigation. Lead ions are harmful if consumed by human beings. Design a project you may undertake, that uses the knowledge learnt in this lesson, to make water from the stream safe for human use?

Activity 7

Work in groups to identify a sub-topic of salts and prepare a 40 min ASEI lesson that integrates IBL using 5E instructional model. You will present the lesson developed through peer teaching for 20 minutes where your colleagues will critique. You will then use the feedback to improve the lesson.

Conclusion
In this topic “Salts” you were given an opportunity to carry out activities illustrating the different levels of IBL. You also prepared and implemented ASEI lessons that integrated IBL using 5E instructional model. You are expected to continue using the 5E instructional model in teaching your lessons.

References:
**Topic Two: Structure and Bonding**

**Introduction**
Welcome to the topic on Structure and bonding. In this section we will explore how to use inquiry based learning using the 5E instructional model in the topic Structure and bonding. This section is divided into preliminaries, content area (properties of ionic and covalent compounds and their structures), sample ASEI lesson plan incorporating the 5E instructional model and lesson preparation. The knowledge and skills learnt can be applied to any other topic in Chemistry

**Preliminaries**

**Rationale**
Chemical bonding is one of the fundamental and key concepts in Chemistry. The concepts associated with chemical bonding and structure such as covalent & ionic bonds, ions, molecules, giant lattices, and hydrogen bonds are very abstract to both teachers and learners. In order to understand these concepts learners need to carryout activities that engage them in exploration, explaining, elaborating to deepen their understanding of structure and bonding. The purpose of this unit is to enhance your ability in inquiry based learning (IBL) and the use of the 5E instructional model in teaching and learning of chemistry.

**Unit Goal**
To promote inquiry based learning through activities developed in structure and bonding based on the 5E instructional model.

**Unit Learning Outcome**
Integrating IBL in ASEI lesson using the 5E instructional model

**Unit Objectives**
By the end of this section, you should be able to

1. Design and carryout activities that enhance inquiry based learning in teaching and learning of structure and bonding
2. Develop an ASEI lesson that integrates IBL using the 5E instructional model
3. Evaluate the level of IBL in activities in the ASEI lesson plan based on the 5E instructional model
4. Appreciate the importance of IBL approach using the 5E instructional model

**Content and Activities in Structure and Bonding**
Substances exist in nature in various forms such as gaseous, liquid and solid. On their own most atoms are unstable and therefore combine with other atoms to gain stability. The attractive force which holds atoms together is called a chemical bond. The force between two oppositely charged ions is called electrostatic which result into formation of an ionic bond, while the force
of attraction between atoms sharing electrons is called a covalent bond. The strength and properties of substances depend on how atoms combine to form a structure. The resultant structure of a given compound influences its physical and chemical properties.

**Teaching and Learning activities in ‘Structure and Bonding’**

In activity one below share your experiences on how you use IBL and 5E instructional model to teach chemistry concepts.

<table>
<thead>
<tr>
<th>Activity one</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on the general session discussion, share your experiences in using</td>
</tr>
<tr>
<td>a) IBL in teaching and learning structure and bonding?</td>
</tr>
<tr>
<td>b) 5E instructional model in teaching and learning of structure and bonding?</td>
</tr>
</tbody>
</table>

**Activity Two**

In this activity you will investigate properties of substances A, B, C and D to establish the type of bonding.

**Materials required:**

| Improvised conductivity tester | boiling tubes |
| Water | Source of heat |
| kerosene, | Spatula |
| Turpentine | Test tube rack |
| Substances A,B,C & D | Water bath |

**Procedure 1: Investigating the Solubility of substances in water**

I. Place a spatula end full of substance A in a clean dry test tube
II. Add water to the test tube while shaking until there is no more observable change, and record your observation in table---
III. Repeat procedures I &II using substances B,C and D respectively in place of A

Note: Do not use *Tap water in this experiment*

<table>
<thead>
<tr>
<th>Substance</th>
<th>Describe your observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>
Discussion Question
Which substances dissolved in water? -----------------------------------------------
---------------------------------------------------------------------------------------------------------------------

Will substances A, B, C and D behave in a similar manner in othersolvents?

Repeat procedure I, II and III above using kerosene and turpentine in place of water and record your results in table ---

<table>
<thead>
<tr>
<th>Substance</th>
<th>Kerosene</th>
<th>Turpentine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe your observation</td>
<td>Describe your observation</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion Questions
a) Which substances dissolved in kerosene and turpentine? --------------------------

b) Explain the behaviour of substances A, B, C and D in the different solvents?

In activity three you will investigate the electrical conductivity of substance A, B, C and D to establish the type of bonding

Activity three

1. In your group carry out the following activities to investigate the electrical conductivity of substances A, B, C and D
2. In your group carry out the following activities to investigate the solubility of substances A, B, C and D in water
Procedure

i. Place two spatula end full of substance A in a clean dry test tube
ii. Insert the electrical conductivity tester and ensure the two electrode wires are immersed in the solid and do not touch each other
iii. Record your observation in table below
iv. Add water to the boiling tube containing substance A and shake well
v. Insert the electrical conductivity tester in the resulting solution and record your observation in table----
vi. Repeat procedures I to V using substances B, C and D respectively in place of A

Note: Ensure that the electrodes of the tester and the test tube are always clean and dry when testing a solid sample.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solid</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

Discussion Questions

1. From your results which substances conducted electricity in
   a) Solid
   b) Solution
2. Explain your observations in (1) above

Which of these four substances, would you expect to conduct electricity in molten state?

Activity four

In your groups, design and carry out an experiment to test the electrical conductivity of zinc (II) chloride and naphthalene in molten state.
Discussion Questions
a) From your observation, which substance conducted electricity in the molten state?
b) Which types of bond exist in zinc (II) chloride and naphthalene?
c) From the results obtained above, deduce the type of bond that exists in the four substances A, B, C and D

d) What conclusion can you make in regard to;
   i. Solubility of ionic and covalent compounds in water and organic solvents
   ii. Electrical conductivity of ionic and covalent compounds when in solid, molten and in solution

Models to illustrate Bonding
The Structure of a compound influences its physical and chemical properties. Diamond and graphite are both forms of carbon. However, they have remarkable differences in their physical and chemical properties.

Activity five

Construct the models of diamond and graphite using the materials provided

Discussion Questions
1. What type of structure is formed by diamond and graphite?
2. Explain how the structure of each model influences its
   i. Melting and boiling
   ii. Electrical conductivity

61
<table>
<thead>
<tr>
<th>TIME</th>
<th>STEP</th>
<th>TEACHING/LEARNING ACTIVITIES</th>
<th>LEARNING POINTS</th>
</tr>
</thead>
</table>
| 5Min | Introduction (Engagement) | • Show a short clip depicting bond types to capture learners’ attention  
• Through Q/A method, teacher to establish the learners’ knowledge on:  
  ➢ how atoms combine to form compounds  
  ➢ type of compounds  
  ➢ Type of bonds that are formed | Combining of atoms by lose or gain of electrons, sharing of electrons  
• Ionic bonds  
• Covalent bonds |
| 25 Min | Lesson Development:  
(i) Exploration | • Learners are given the procedure of testing the electrical conductivity of the substances provided. (see worksheet)  
• Learners investigate the electrical conductivity of compounds A, B, C and D  
• Learners record observations  
  ➢ Learners to identify which of substances conduct electricity in various states (solid, molten & in solution)  
• Learners to design a procedure to investigate the electrical conductivity of zinc chloride and Naphthalene  
• Learners to give explanation to their group findings  
  ➢ Learners to draw a generation on the electrical conductivity of substances based on bond type  
• Teacher to harmonize / clarify learners’ finding in order to make a reasonable generalization  
  ➢ Apply the knowledge in predicting electrical conductivity of substances in the environment | Manipulation of apparatus  
• Making correct observation  
• Recording of observations  
• Cooperation/collaboration in group work  
Analyzing information,  
Critical thinking on why there is variation in electrical conductivity between ionic and covalent compounds.  
Giving reasonable explanations, communicating scientific concepts.  
Application of knowledge to draw generalizations, make collect predictions on electrical conductivity, drawing rational conclusions |
| 5 Min | Conclusion | Teacher to summarize the lesson by:  
• explaining the basis of electrical conductivity in solid, molten or in solution  
• relating bond type to electrical conductivity | Listening, recording of explanations |
Activity Six

Critique the sample ASEI lesson plan provided in light of inquiry based learning and use of the 5E instructional model. Identify the strengths and areas that require improvement.

Sample Lesson

IBL LESSON PLAN ON STRUCTURE & BONDING

<table>
<thead>
<tr>
<th>Date:</th>
<th>Time</th>
<th>Duration: 40 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class: Form two</td>
<td>Class size</td>
<td></td>
</tr>
<tr>
<td>Topic</td>
<td>Structure and Bonding</td>
<td></td>
</tr>
<tr>
<td>Learning area</td>
<td>Influence of bond type and forces of attraction on physical properties of substances</td>
<td></td>
</tr>
<tr>
<td>Key concepts</td>
<td>Relating Electrical conductivity to presence of ions or free electrons</td>
<td></td>
</tr>
<tr>
<td>Learning objectives</td>
<td>1. Distinguish between bond types on the basis of electrical conductivity of substances</td>
<td></td>
</tr>
</tbody>
</table>
| Prerequisite knowledge | • Role of outer electrons in chemical bonding  
• Electron transfer and ionic bonding  
• Electron sharing and covalent bonding  
• Electrostatic forces of attraction |
| Scientific skills | Manipulative, observation and recording skills |
| Thinking skills | Attributing, comparing and, predicting and making generalization |
| Scientific attitudes | Cooperation, interest and exploring nature |
| T/L materials/aids/resources | Conductivity tester, beakers (100ml), water and source of heat. Sodium chloride, zinc chloride, sucrose and naphthalene |

Activity seven

In your group identify a subtopic in structure and bonding and prepare a 40 minutes ASEI lesson plan that incorporates IBL and the 5E instructional model. You will present the lesson developed through peer teaching for 20 minutes, where your colleagues will critique. You will then use the feedback to improve the lesson.

ASEI lesson plan provided in light of inquiry based learning and use of the 5E instructional model.
Conclusion
In this topic you were given an opportunity to carry out activities illustrating different levels of IBL. You also prepared and implemented ASEI lessons that integrated IBL using 5E instructional model through peer teaching. You are now expected to continue practicing IBL approach using the 5E instructional model in your Chemistry classrooms.
MATHEMATICS

Topic One: Fractions

Introduction
Welcome to Mathematics topic one on Fractions. In this topic, we shall discuss 5E Instructional Model in Inquiry Based Learning in Mathematics, particularly on Fractions. You will also explore the difficult areas in teaching and learning of the topic, and develop activities that can help learners understand the concepts better.

Rationale
Fractions are very important in everyday life and used in many ways.

Why do we use fractions?
In everyday activities, it is not always possible to use whole numbers to describe quantities. Sharing is a common social activity and knowledge of fractions is paramount. Architecture, hotel industry (cooking of foodstuff), music are some of the areas that heavily employ the knowledge of fractions. Knowledge and clear understanding of fractions are often necessary for advancing sound arguments in the society.

A Training Needs Assessment (TNA) conducted by CEMASTEA indicated that fractions as a topic of concern to the teachers and to the learners (CEMASTECA, 2007). The findings further indicated that teachers did not adequately arouse learners’ interest and curiosity and there was an inadequate use of innovative activities that relate to real life situations during the teaching and learning of the topic. 5E Instructional Model in Inquiry Based Learning offers an opportunity to enhance the use of innovative activities that relate to real life situations in the teaching and learning of fractions. It is our hope that this session will enhance your knowledge and skills in 5E Instructional Model and IBL and in its application teaching and learning of fractions.

Goal
To improve quality of teaching and learning in Mathematics through the use of ‘5E Instructional Model in Inquiry Based Learning’

Objectives
By the end of the session you should be able to:
1. Design and develop teaching/learning activities which promote Inquiry based Learning (IBL) in the teaching of fractions
2. Design ASEI Lesson plans that incorporate IBL using 5E instructional model
3. Appreciate the importance of IBL in the teaching and learning of fractions

Learning Outcome
Demonstrate the ability to effectively prepare and implement ASEI lessons that incorporate 5E instructional model in inquiry-based learning
Developing teaching and learning activities

Activity 1
What would you say to a child who thought that the shaded portion in the larger circle could not be a quarter because it is not the same size as the quarter in the smaller circle in the diagrams shown below?

Activity 2
1. What is a fraction?
2. Where did fraction originate from?
3. How do you introduce fractions? Demonstrate the following fractions.

You may have come up with the following:

Any number that does not represent a ‘whole’ is called a "fraction". The term ‘fraction’ is derived from the Latin word *fractum*, meaning *to break*. From this literal meaning, an early concept of the fraction was something less than a *whole*.

This interpretation is the one that is frequently used when introducing fractions to children. Our present day symbolization for fractions comes from the Hindus, who placed the numerator above the denominator. This notation was copied by the Arabs, who added the line of separation between the two numbers.

Introductory fraction instruction generally focuses on the *part-whole* interpretation. This interpretation depends on the ability to partition a continuous quantity (*region model*) or a set of discrete objects into equal-sized parts (*set model*).

In *mathematics* a fraction is defined as an indicated quotient of two quantities. The dividend is the numerator and the divisor is the denominator.
Region model (part of a whole)

Length, area and volume measurers are part of the concept of continuous quantity. In this case the unit or the whole is one object such as a circle, square of a piece of paper.

In first above the circle has been subdivided into nine equal parts and one part is shaded part (1/9). In the second figure the shaded part is one of the four equal parts. When using the region model, learning is enhanced when learners engage in portioning activities. Without this personal experience of portioning figures, learners are unable to use the model in problem-solving activities.

Length model

The length model is an effective one for comparing fractions. A set of fraction strips can easily be made and used to compare unit fractions and to generate equivalent fractions.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>1/3</td>
<td>1/3</td>
<td>1/3</td>
</tr>
<tr>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
</tr>
<tr>
<td>1/5</td>
<td>1/5</td>
<td>1/5</td>
</tr>
<tr>
<td>1/6</td>
<td>1/6</td>
<td>1/6</td>
</tr>
</tbody>
</table>

The chart above can easily be obtained by paper folding.
Set model

When the unit consists of objects, the unit is said to be discrete, and can be portioned into different sized groups of the objects. Symbolically two numbers are used to represent each fraction number: the numerator (first number) denotes the number of parts identified and the denominator (second number) indicates into how many equal parts the whole has been separated (divided).

The figure below shows balls packed in a box. The total number of balls is 15. This number, 15 now forms the whole. Nine are shaded and six are not shaded.

```

```

i. Express the number of black balls as a fraction of all the balls
ii. Express the number of white balls as fraction of all the balls

<table>
<thead>
<tr>
<th>Activity 3</th>
<th>Name types of fractions and explain how they differ from each other?</th>
</tr>
</thead>
</table>

You may have come up with the following:-

✓

Types of fractions

**Proper Fraction**
A fraction whose numerator is smaller than its denominator e.g. \( \frac{1}{3}, \frac{1}{4}, \frac{1}{2} \)

**Improper Fraction**
A fraction whose numerator is greater than its denominator e.g. \( \frac{5}{3}, \frac{7}{4}, \frac{9}{4} \)

**Mixed number**
A number made of a whole number part and a proper fraction \( 1\frac{1}{3}, 2\frac{1}{4}, 3\frac{1}{2} \)

Proper and improper fractions are collectively called common fractions or vulgar fractions.

An improper fraction or top-heavy fraction is one whose absolute value of the numerator is greater than or equal to the absolute value of the denominator (e.g. \( \frac{9}{4} \)).

A **mixed number** is the sum of a whole number and a proper fraction. This sum is simplified without the use of any visible operator such as "+". A mixed number can be converted to an improper fraction in three steps:
1. Multiply the whole part by the denominator of the fractional part (Why?).
2. Add the numerator of the fractional part to that product.
3. The resulting sum is the numerator of the new fraction; the new numerator is greater than the denominator hence the name: improper fraction

Similarly, an improper fraction can be converted to a mixed number:
1. Divide the numerator by the denominator.
2. The quotient (without remainder) becomes the whole part and the remainder becomes the numerator of the fractional part.

Equivalent fractions

You may have come with the following
An equivalent fraction means that the two or more fractions have the same value. The notion that a quantity can be expressed with different numbers (e.g. $\frac{1}{4}, \frac{2}{8}, \frac{4}{16}$ etc all naming the same amount) is not easy for students to grasp. The idea of equivalent fractions can be illustrated by the three different shadings of the same part of a rectangle as shown below.

1. $\frac{1}{4}$
2. $\frac{2}{8}$
3. $\frac{4}{16}$

Computation involving fractions

Addition of fractions
- Addition of fractions with the same denominator
- Addition of fraction involving one renaming
- Addition of fractions involving renaming both fractions
- Addition involving mixed numbers
You may have come up with the following
1) Using region model

Step 1: Show $\frac{1}{4}$ as part of a whole

From the whole, shade $\frac{1}{4}$

Step 2
Add $\frac{2}{3}$ by shading it out

The shaded parts add up to 11 parts out of 12 therefore

$$\frac{1}{4} + \frac{2}{3} = \frac{11}{12}$$

Adding using the set model (fraction as part of a group)
The denominator of fraction serves as a label naming the number of parts into which the whole must be divided into. In terms of equivalent fractions with the same denominator,

$$\frac{1}{4} + \frac{2}{3} = \frac{3}{12} + \frac{8}{12} = \frac{11}{12}$$
The pictorial representation may be the following. The whole has 12 items. The sum of the colored balls is as shown below

\[
\frac{3}{12} + \frac{3}{12} + \frac{8}{12} = \frac{11}{12}
\]

Activity: Beginning with three shaded strips out of 12, shade 8 more strips

The 8 additional shaded strips are indicated by (√) as shown on the right. Symbolically the above illustration becomes:

\[
\frac{1}{4} \text{ (or } \frac{3}{12} \text{)} + \frac{2}{3} \text{ (or } \frac{8}{12} \text{)} = \frac{11}{12}
\]

3. The addition is done by making the fractions to have a common denominator, which is the LCM, then the addition is done. This is comparable to example 2 above where equivalent fractions were used.

Activity 6

How do you add $2\frac{3}{5} + 1\frac{1}{5}$
You may have represented as below

The sum of the whole number parts (Number of full shaded rectangles) is 3
The sum of the fractional parts (Number of shaded rectangular strips) is 4 out of 5

Add the whole parts and then the fractions using the LCM.

Subtraction of fractions

Activity 7
Show at least two ways this subtraction can be done
1) \( \frac{5}{6} - \frac{2}{3} \)
2) \( 2\frac{4}{5} - 1\frac{3}{5} \)

You may have come up with the following explanation

The denominator of fraction serves as a label naming the number of parts into which the whole must be divided into \( \frac{5}{6} = \frac{2}{3} \) becomes \( \frac{5}{6} - \frac{4}{6} \), in terms of equivalent fractions with the same denominator.

What is \( \frac{5}{6} - \frac{4}{6} \)? How can we illustrate this?

Possible illustration:
Supposing you have a rectangle divided into six equal portions as shown below
\( \frac{5}{6} - \frac{4}{6} \)
Step 1
5/6 of the portions are shaded.

Step 2
Learners are asked to rub off (sections marked with X) four portions of the five shaded portions.

Step 3
Only one portion remains shaded (1/6) as shown below;

Therefore, \( \frac{5}{6} \times \frac{4}{6} = \frac{1}{6} \)

Multiplication of fractions

Multiplication and division of fractions are areas that pose many difficulties for learners. It is important to use activities that will enhance the understanding of the same.

Multiplication
Learners may by now know how to add or subtract the whole numbers after they have found equivalent fractional parts. They may then assume logically they can do the same when multiplying, yielding answers like

\[
2 \times \frac{3}{4} = \frac{2}{2} \times \frac{3}{4} = \frac{6}{8}, \quad \text{or} \quad 2 \frac{1}{2} \times 4 \frac{1}{4} = 8 \frac{1}{8}.
\]
(a) Whole number \times fraction

Multiplication as repeated addition

You may have come up with the following

\[ 5 \times \frac{2}{3} \] mean 5 groups of \( \frac{2}{3} \) of something.

Therefore \[ 5 \times \frac{2}{3} = \frac{2}{3} + \frac{2}{3} + \frac{2}{3} + \frac{2}{3} = \frac{10}{3} \] (repeated addition) = 3 and \( \frac{1}{3} \)

(b) Show learners direct multiplication of \( 5 \times \frac{2}{3} \)

(c) Fraction \times fraction

Activity 9

1. What does the following mathematical statement mean? \( \frac{2}{3} \times \frac{4}{5} \)

2. Use at least two methods to work-out the question above
**Division of fractions**
Division with fractions poses challenges to many learners.

**Activity 10**
What does \( \frac{12}{4} = 3 \) mean?

**Activity 11**
Consider the question \( 2 + \frac{2}{3} \). Create a scenario to help explain this question?

**Activity 12**
Consider the question \( \frac{2}{3} + \frac{3}{4} \). Create a scenario to help explain and solve this question?

**Comparing fractions**

**Activity 13**
1. In a certain country, \( \frac{2}{7} \) of the population live below the poverty line while in a second country the population at this level is \( \frac{3}{11} \). Which country has higher level of poverty?
2. Ten years ago \( \frac{1}{9} \) of the rivers in a country were polluted. Currently the fraction is \( \frac{2}{19} \). Is the situation better or worse?

**Group Tasks**
1. Identify difficult areas in the teaching and learning of fractions
2. Develop teaching and learning activities which promote IBL and incorporate 5E instructional model, in the teaching of fractions.
3. Prepare a 30-minute lesson for peer teaching incorporating the activities in (2) above.
References
3. KLB, (2005), *Secondary Mathematics Book 1*, KLB.
TOPIC: Fractions

SUBTOPIC: Multiplication of fractions

RATIONALE: Topic has many applications in everyday activities, such as in describing quantities that are not in whole. Sharing is also a common social activity and knowledge of fractions is paramount. Architecture, hotel industry (cooking of foodstuff), music also heavily employ the knowledge of fractions.

OBJECTIVE/S: By the end of the lesson, the learner should be able to multiply fractions

Prerequisite knowledge and skills: The areas that are relevant to this topic are many. They include numbers and addition of fractions.

Teaching / Learning Resources: Charts

References: 1. Advancing In Mathematics Form 1
2. Secondary Mathematics for students KLB Book 1
3. Exploring mathematics Book 1

<table>
<thead>
<tr>
<th>Stages /Time</th>
<th>Teaching/Learning Activities</th>
<th>Learning Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction (5 minutes)</td>
<td>Review meaning of fractions using question and answer method</td>
<td>Explore fraction as part of a whole and as part of a region</td>
</tr>
<tr>
<td>Development (25 minutes)</td>
<td>Students’ works in groups of five are provided with the question below to work out. And present their work\n\n1. What does the following mathematical statement mean? $\frac{2}{3} \times \frac{4}{5}$\n2. Use at least two methods to work out the question above\nTeacher harmonizes the findings\nRevisit how to carry out multiplication through Q/A</td>
<td>1. Demonstrate the multiplication using drawings as shown below\n2. Demonstrate using dots\n3. Multiply directly and relate to above two methods</td>
</tr>
<tr>
<td>Conclusion (5 minutes)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
KCSE (2014) Evaluation question

1. Ntutu had cows, sheep and goats in his farm. The number of cows was 32 and the number of sheep was twelve times the number of cows. The number of goats was 1344 more than the number of sheep. If he sold ¾ of the sheep, find the number of goats that remained.

2. A strip of metal was painted in three different colours. Two fifths of the strip were painted white, ⅕ of the strip was painted green and the remaining part was painted black. Which is the correct order of writing the fractions of the strip, painted from the smallest to the largest?
**Topic Two: Vectors**

Welcome to this section of Mathematics. In this section, we shall discuss scalar and vector quantities, vector notation, representation of vectors, equivalent vectors, the addition of vectors, multiplication of a vector by a scalar, column vectors, position vectors, magnitude and direction of a vector, the midpoint of a vector and translation vector. These topics will suffice in bringing out IBL using the 5E instructional model more clearly. You will also explore difficult areas in teaching and learning of vectors and suggest activities which you can use to make key concepts in vectors easily understood by learners. You will be encouraged to design activities that incorporate inquiry based learning using the 5E instructional model to help learners grasp the concepts better.

**Rationale**

You use vectors in almost every activity you do. Examples of everyday activities that involve vectors include:

- Breathing (your diaphragm muscles exert a **force** that has a magnitude and direction)
- Walking (you walk at a **velocity** of around x km/h in the direction of saying the bathroom)
- Going to school (the bus/van has a **length** of about y m and is headed towards your school)
- Lunch (the **displacement** from your classroom to the canteen is about d m in a northerly direction)

The teachers and learners have challenges in teaching & learning of vectors especially on vector notation and representation, multiplication of a column vector by a scalar, position vector, magnitude and direction of a vector, among others. Thus, the need for teachers to design suitable teaching/learning activities in the topic of vectors

**Objectives**

By the end of the session you should be able to:

1) Design and develop teaching/learning activities which promote ‘Inquiry Based Learning’ (IBL) in the teaching of ‘vectors’
2) Develop ASEI lesson plans that incorporate IBL using 5 E instructional model
3) Appreciate the importance of IBL in the teaching/learning of ‘vectors’

**Learning Outcome**

Demonstrate ability to effectively prepare and implement ASEI lessons that incorporate ‘inquiry based learning’ using 5 E instructional model
Scalar and Vector Quantities

Activity 1

How would you teach the difference between a scalar and a vector quantity? (Pair & Share)

You may have come up with some of the following:-

I would first ask the students to name some of the quantities they have come across in their daily activities in school, home and in the environment. I expect them to give some amounts or numbers of something. The class will then categorize the data collected into those with magnitude only and those with magnitude and direction. I will then help them define a scalar and a vector quantity giving some examples for illustration as seen below.

- A scalar quantity has **magnitude**, but not direction.

- Examples of Scalar Quantities

  - A pen of length "10 cm". The length 10 cm is a **scalar quantity** - it has a magnitude, but no direction is involved
  - The speed of a tractor is “35 km/h”. The speed 35km/hr is a scalar quantity – it has a magnitude 35km/hr but no direction is involved

Other examples of scalar quantities are: volume, density, temperature, mass, time, distance, work and energy.

- A vector is a quantity that has both **magnitude** and **direction**. (Magnitude just means 'size'.)

- Examples of Vector Quantities

  - I travel 30 km in a Northerly direction (magnitude is 30 km, direction is North - this is a displacement vector)
  - The train is going 80 km/h towards Sydney (magnitude is 80 km/h, direction is 'towards Sydney' - it is a velocity vector)
  - The force on the bridge is 50 N acting downwards (the magnitude is 50 Newton and the direction is down - it is a force vector)
Other examples of vectors include: - acceleration, momentum, angular momentum, magnetic and electric fields.

Vector Notation and Representation

Activity 2

I will first draw a directed line segment $AB$ as shown below in figure 1 below

![Diagram of AB vector]

$A$ $B$

Figure 1

I will then lead the students in discussing the following:-

- Use of **bold capital letters** to name vectors such as $\mathbf{AB}$ from the above diagram.
- Using an arrow above the same vector can be named like this: $\vec{AB}$
  Using a wave below the same vector can also be named like this: $\sim \mathbf{AB}$
- In the diagram above, point $A$ is called the **initial point** and $B$ the **terminal point**. The vector $\mathbf{AB}$ is referred to as a ‘**displacement vector**’ or a ‘**localized vector**’.
- The **length** of the arrow indicates the **magnitude** of the vector $\mathbf{AB}$ represented by $|\mathbf{AB}|$. The **direction** of the vector $\mathbf{AB}$ is represented by the **direction** of the arrow.

Sometimes a vector can be denoted by a single **small letter** $\mathbf{a}$ or $\mathbf{a}$ as shown in figure 2 below.
Figure 2
The vector \( \vec{a} \) given above is referred to as a ‘free vector’. We draw them without any fixed position.

**NB:** In books you will find vectors written as \( \overrightarrow{an} \) or \( \overrightarrow{AB} \) but when writing you will be using \( \vec{a} \) or \( \overrightarrow{AB} \).

**Activity 3**

Describe vectors \( a, b, c, d \) & \( e \) in figure 3 given below.
(Pair & Share)

![Figure 3](image)

You may have come up with some of the following:-

- Vector \( a \) has a direction ‘up’ and a magnitude of 3cm
- Vector \( b \) has the same direction as vectors \( a \). The magnitude of vector \( b \) is 1.5cm. Hence vector \( b \) is half of vector \( a \)
- Vector \( c \) has the same magnitude as vector \( a \), but has a different direction – to the right
Vector \( d \) has the same magnitude as vectors \( a \) & \( c \). However vector \( d \) has a direction ‘down’ and hence vectors \( a \) & \( d \) is in **opposite** directions. Vector \( d \) is half of vector \( b \) but in opposite direction.

Vector \( e \) has the same magnitude as vector \( b \) but in **different** direction – sideways to the right ‘up’.

**Equivalent Vectors**

**Activity 4**

Find relations between the vectors shown in figure 4 below. *(Pair & Share)*

**Figure 4**

You may have come up with some of the following:-

First, it’s good to note that, vectors are equivalent or equal if they are

(i) in the same direction, *and*

(ii) they have the same magnitude (length)

Thus, the following are some of the relations; -

- \( AB = KL \). This means \( AB \) & \( KL \) are of equal magnitude and same direction
- \( CD = -MN \). This means \( CD \) & \( MN \) are of equal magnitude but in the opposite direction
- \( CD = 2AB \). This means \( CD \) is twice \( AB \) and in the same direction

NB; - Find other relations.
Column Vectors
Activity 5a

How would you introduce the concept of column vector? (Pair & Share)

You may have come up with the following:

- First draw a diagram showing vector v

![Diagram of vector v with x and y components]

- Reading from the diagram above, the x-component of the vector v is 7 units while the y-component of the vector v is 5 units
- We can write these vector components using subscripts as follows: 
  \[ v_x = 7 \text{ units} \quad \text{and} \quad v_y = 3 \text{ units} \]
- Vector v can be expressed as a column vector and written as:
  \[ \mathbf{v} = \begin{pmatrix} 7 \\ 5 \end{pmatrix} \]

Activity 5b

Investigate the vectors shown below. (Pair & Share)

\[
\begin{align*}
AB &= \begin{pmatrix} 3 \\ -2 \end{pmatrix}, & CD &= \begin{pmatrix} 6 \\ -4 \end{pmatrix}, & EF &= \begin{pmatrix} -2 \\ 1 \end{pmatrix}, & GH &= \begin{pmatrix} 3 \\ -2 \end{pmatrix}, & JK &= \begin{pmatrix} -4 \\ 3 \end{pmatrix}, \\
MN &= \begin{pmatrix} 6 \\ 0 \end{pmatrix}, & PQ &= \begin{pmatrix} 6 \\ -3 \end{pmatrix} & \text{and} & RS &= \begin{pmatrix} 4 \\ 3 \end{pmatrix}.
\end{align*}
\]
You may have come up with some of the following:-

- All the vectors given are column vectors.
- $\overrightarrow{AB} = \overrightarrow{GH}$. This means $\overrightarrow{AB}$ and $\overrightarrow{GH}$ are of equal magnitude and same direction.
- $\overrightarrow{JK} = -\overrightarrow{RS}$. This means $\overrightarrow{JK}$ and $\overrightarrow{RS}$ are of equal magnitude but in the opposite direction.
- $\overrightarrow{CD} = 2\overrightarrow{AB}$. This means $\overrightarrow{CD}$ is twice $\overrightarrow{AB}$ and in the same direction.
- $\overrightarrow{PQ} = -3\overrightarrow{EF}$. This means $\overrightarrow{PQ}$ is thrice $\overrightarrow{EF}$ and in the opposite direction.
- $\overrightarrow{MN}$ has a magnitude of 6 units and direction to the right.

Activity 5c

Discuss how you would form column vectors from the coordinates, $A(2,7)$, $B(3,2)$, $C(4,6)$, $D(6,-4)$, $E(-2,2)$ and $F(-1,-3)$ and investigate their relationships. (Pair & Share)

You may have come up with some of the following:-

$$\overrightarrow{AB} = \begin{pmatrix} 3 \\ 2 \\ -2 \\ -7 \end{pmatrix} = \begin{pmatrix} 1 \\ -5 \end{pmatrix}, \quad \overrightarrow{EF} = \begin{pmatrix} -1 \\ -1 \\ -2 \\ -2 \end{pmatrix} = \begin{pmatrix} 1 \\ -5 \end{pmatrix}$$

$\Rightarrow$ Given $P(x_1, y_1)$ and $Q(x_2, y_2)$, then vector

$$\overrightarrow{PQ} = \begin{pmatrix} x_2 - x_1 \\ y_2 - y_1 \end{pmatrix}$$

$\Rightarrow \overrightarrow{AB} = \overrightarrow{EF}$. This means vectors $\overrightarrow{AB}$ and $\overrightarrow{EF}$ have the same magnitude and direction.

NB: - Look other more column vectors and their relationships.

Magnitude and Direction of a $2$-dimensional Vector

Activity 6a

How would you find the magnitude and direction of a vector? (Pair & Share)
You may have come up with some of the following:-

✓ You will indicate the magnitude of a vector using vertical lines on either side of the vector name. For example, the magnitude of vector PQ is written |PQ|.

✓ From figure 5 above, the vector components of vector v are \( v_x = 7 \) units and \( v_y = 5 \) units. Vector v and its x and y components form a right angled triangle as seen below:

\[ v_x = 7 \]
\[ v_y = 5 \]

The magnitude of a vector is simply the length of the vector. We can use Pythagoras' Theorem to find the length of the vector v above.

Hence, the magnitude of \( v = |v| = \sqrt{7^2 + 5^2} = \sqrt{74} = 8.60 \) units

✓ To describe the direction of the vector, we normally use degrees (or radians) from the horizontal, in an anti-clockwise direction. One radian is approximately \( 57.3^° \)

\[ 1^c \approx 57.3^° \]

Thus, \( \tan \theta = \left( \frac{7}{5} \right) = 0.7143 \Rightarrow \theta = \arctan(0.7143) = 35.5^° = 0.62 \) radians

✓ So the vector v has a magnitude of 8.60 units and a direction of 35.5°

Activity 6b

| How would you find magnitude and direction of the vectors shown in figure 6 below? (Pair & Share) |

\[ \begin{array}{c}
\text{a} \\
\text{b} \\
\text{c} \\
\text{d} \\
\text{e}
\end{array} \]
First you will find the vector components of vectors shown in figure 6 above. That is; \( v_x = m \) units and \( v_y = n \) units.

We then use Pythagoras’ Theorem to find the length of the vectors given. That is, the magnitude of a vector \( v \) = \( \sqrt{m^2 + n^2} \) units.

The direction of the vector shown will be given by finding the arctan of the ratio of the opposite and hypotenuse sides.

Now, using this information find the magnitudes and directions of the vectors shown in figure 6.

**Vector Addition**

a) Addition of Vectors Using Triangle Law

Activity 7a

How would you add two vectors that are drawn separately as in figure 7 (i) below? *(Pair & Share)*

You may have come up with some of the following:

- The addition of two vectors is accomplished by laying the vectors head to tail in sequence to create a triangle such as is shown in figure 7 (ii) below.

**Figure 7**

Thus, the resultant vector \( c = a + b \).
b) Adding Vectors Using Parallelogram Law

Activity 7b

How would you add vectors \(a\) and \(b\) shown in figure 8 (i) below? (Pair & Share)

![Vector Diagram](image)

**Figure 8**

You may have come up with some of the following:-

The parallelogram in (ii) above is an alternative method to using triangles. If we add the **blue** vector (\(b\)) and the **black** vector (\(a\)) the **resultant vector** is the **red** vector (\(c\)) in the direction \(\theta^0\).

Thus, \(c = a + b\)

NB: - This concept will be revisited when discussing parallel lines and collinearity in Vector 2.

Activity 7c

In the diagram given below, vector \(p = AF\).

Express vector \(p\) in other ways.

Write down a single vector equivalent to (i) \(AB + BC\) (ii) \(AD + DC\) (iii) \(EH + HE\) (iv) \(AH + HG + GB\) (v) \(AD + DC + CA\) (vi) \(DC + BD\) Pair & Share

![Vector Diagram](image)
Vector p can be expressed in some of the following ways:

\[ p = AF = AC + CF \]
\[ p = AF = AE + EF \]
\[ p = AF = AD + DF \]
\[ p = AF = AB + BC + CF, \text{ etc} \]

Thus in vector addition, the displacement from A to C followed by C to F, gives a resulting displacement vector AF.

(i) AC (ii) AC (iii) O (iv) AB (v) O (vi) Cannot be expressed into a single vector, hence not compatible/not applicable

Thus the concept of ‘head to tail’ or ‘nose to tail’ sequence gives a resulting displacement vector.

Activity 7d

Using the figure given below, illustrate the sums of the following vectors: - (i) \( a + c \) (ii) \( f + g \) (iii) \( b + e \) (iv) \( c + d \) (v) \( d + e + b \) relating column vectors of individual vectors to that of their sum

(a) Design other vector sums. (Pair & Share)

The sums of the vectors (i) and (ii) are shown in red. Illustrate the other sums of vectors.

You may have come up with some of the following illustrations and their respective column vectors:
Subtraction of Vectors

Activity 8a

\[ \mathbf{a} + \mathbf{c} = \begin{bmatrix} 7 \\ 3 \end{bmatrix} \quad \& \quad \mathbf{f} + \mathbf{g} = \begin{bmatrix} 4 \\ 7 \end{bmatrix} \]

Comment on the vectors given below. (*Pair & Share*)

\[ \mathbf{a} = \begin{bmatrix} 5 \\ -3 \end{bmatrix} \Rightarrow -\mathbf{a} = \begin{bmatrix} -5 \\ 3 \end{bmatrix} \]

You may have come up with some of the following:

The above two are of the same magnitude and in the opposite direction. They can be represented diagrammatically as shown below.
NB: Both vectors have the same length (magnitude) and are parallel to each other but are in opposite directions.

Activity 8b

Given that \( \mathbf{a} = \begin{pmatrix} 5 \\ -1 \end{pmatrix} \) and \( \mathbf{b} = \begin{pmatrix} -6 \\ 9 \end{pmatrix} \), find (i) \( \mathbf{a} - \mathbf{b} \) (ii) \( \mathbf{b} - \mathbf{a} \) and make comments. (Pair & Share)

You may have come up with some of the following; 

(i) \( \mathbf{a} - \mathbf{b} = \mathbf{a} + (-\mathbf{b}) = \begin{pmatrix} 11 \\ -10 \end{pmatrix} \)  
(ii) \( \mathbf{b} - \mathbf{a} = \mathbf{b} + (-\mathbf{a}) = \begin{pmatrix} -11 \\ 10 \end{pmatrix} \)

Vectors (\( \mathbf{a} - \mathbf{b} \)) and (\( \mathbf{b} - \mathbf{a} \)) are equal magnitude and in opposite direction.

Scalar Multiplication

We can increase or decrease the magnitude of a vector by multiplying the vector by a scalar.

Activity 9a

Discuss the relations between the vectors given in figure 9 below. (Pair & Share)
Vectors \( \mathbf{p}, \mathbf{s} \) and \( \mathbf{t} \) have a magnitude of 4 units each. Vectors \( \mathbf{p} \) and \( \mathbf{t} \) have a direction ‘up’ while vector \( \mathbf{s} \) has a direction ‘down’ which is opposite of the direction of vectors \( \mathbf{p} \) and \( \mathbf{t} \). Thus, we write: \( \mathbf{p} = \mathbf{t} \) and \( \mathbf{p} = \mathbf{t} = -\mathbf{s} \). We say vectors \( \mathbf{p} \) and \( \mathbf{t} \) are equivalent (equal).

Note: We cannot write \( \mathbf{p} = \mathbf{s} \) because even though \( \mathbf{p} \) and \( \mathbf{s} \) have the same magnitude (4 units), they have a different direction. Hence, they are not equivalent.

Vector \( \mathbf{r} \) has a magnitude of 2 units and direction ‘up’ while vector \( \mathbf{p} \) has a magnitude of 4 units and direction ‘up’. Thus, vector \( \mathbf{p} \) is twice vector \( \mathbf{r} \). This can be expressed as \( \mathbf{p} = 2\mathbf{r} \).

We can also write \( \mathbf{s} = -2\mathbf{r} \).

NB: Each of the above relations is a scalar multiplication. This concept will be revisited later when studying parallel lines and collinearity.

Activity 9b

In the set of column vectors given below, find the scalar multiples of these vectors (Pair & Share)

Consider the column vectors:

\[
\begin{align*}
\mathbf{AB} &= \begin{pmatrix} 2 \\ 3 \end{pmatrix}, & \mathbf{CD} &= \begin{pmatrix} 4 \\ 6 \end{pmatrix} & \text{and} & \mathbf{EF} &= \begin{pmatrix} -6 \\ -9 \end{pmatrix}
\end{align*}
\]

You may have come up with some of the following:-

- \( \mathbf{CD} = 2\mathbf{AB} \) or \( \mathbf{AB} = \frac{1}{2}\mathbf{CD} \), \( \mathbf{EF} = -3\mathbf{AB} \) or \( \mathbf{AB} = -\frac{1}{3}\mathbf{EF} \) and \( \mathbf{CD} = -\frac{1}{3}\mathbf{EF} \) or \( \mathbf{EF} = -1.5\mathbf{CD} \)

NB: Each of these statements is a scalar multiplication.

2.2.9 Position Vector
Activity 10a

How can you introduce the concept of position vector using points P(3,5) and Q(4,-2) (Pair & Share)

You may have come up with the following:-

- A vector \( \mathbf{OP} \) which starts from the origin (0,0) will locate the position coordinates of point P. Thus, \( \mathbf{OP} \) is referred to as a **position vector** of point P.
- Likewise, vector \( \mathbf{OQ} \) starts from the origin (0,0) and locates the position coordinates of point Q. Thus, \( \mathbf{OQ} \) is referred to as the **position vector** of point Q.
- The position vectors are drawn in the diagram below.

![Diagram showing vectors OP and OQ]

NB: - Position vectors are usually denoted by a small letter, the same as the letter of the point. Hence, the position vector of points P and Q are:

\[
\mathbf{p} = \mathbf{OP} = \begin{pmatrix} 3 \\ 5 \end{pmatrix} \quad \text{and} \quad \mathbf{q} = \mathbf{OQ} = \begin{pmatrix} 4 \\ -2 \end{pmatrix}
\]

Activity 10b

(a) From the diagram shown in activity 10a above, find a relation between vectors \( \mathbf{PQ} \), \( \mathbf{p} \) and \( \mathbf{q} \).

(b) Given that points \( X(4,6) \) and \( Y(5,-4) \), find a relation between vectors \( \mathbf{x}, \mathbf{y} \) and \( \mathbf{YX} \). 


a) From the diagram,
\[ \mathbf{PQ} = \begin{pmatrix} 1 \\ -7 \end{pmatrix} \]
Now, \( \mathbf{p} = \begin{pmatrix} 3 \\ 5 \end{pmatrix} \) and \( \mathbf{q} = \begin{pmatrix} 4 \\ -2 \end{pmatrix} \)
\[ \Rightarrow \mathbf{PQ} = \mathbf{q} - \mathbf{p} \]

b)
\[ \mathbf{x} = \begin{pmatrix} 4 \\ 6 \end{pmatrix} \text{ and } \mathbf{y} = \begin{pmatrix} 5 \\ -4 \end{pmatrix} \]
\[ \mathbf{YX} = \mathbf{x} - \mathbf{y} = \begin{pmatrix} 4 \\ 6 \end{pmatrix} - \begin{pmatrix} 5 \\ -4 \end{pmatrix} = \begin{pmatrix} -1 \\ 10 \end{pmatrix} \]

**Zero Vectors**

Activity 11

How can you define a Zero vector? *(Pair & Share)*

You may have come up with the following:-

- A **zero vector** has a magnitude of 0 and has no direction. It is also referred to as a **null vector**.
- A vector may have zero magnitudes at an instance in time. For example, a boat bobbing up and down in the water will have a **positive** velocity vector when moving up, and a **negative** velocity vector when moving down. At the instant when it is at the top of its motion, the magnitude is **zero**.
- In a tug-of-war, the two teams are evenly matched at a certain instant and neither side is able to move. In this case, we would have:
\[ \mathbf{OA} + \mathbf{OB} = \mathbf{O} \]
The 2 force vectors \( \mathbf{OA} \) and \( \mathbf{OB} \), operating in opposite directions, cancel each other out. Example,
\[ \begin{pmatrix} 6 \\ -7 \end{pmatrix} + \begin{pmatrix} -6 \\ 7 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \]
Also, \( \mathbf{a} - \mathbf{a} = \mathbf{0} \)
- Give other examples that give rise to zero vectors
Midpoints
Activity 12a

Using figure 10, show that \( \mathbf{m} = \frac{1}{2}(\mathbf{a}+\mathbf{b}) \), where \( \mathbf{m}, \mathbf{a} \) and \( \mathbf{b} \) are position vectors of points \( \mathbf{M}, \mathbf{A} \) and \( \mathbf{B} \) respectively.
Verify that \( \mathbf{M}(6,7) \) (Pair & Share)

You may have come up with the following:-

a) From figure 10 above, \( \mathbf{AM} = \mathbf{MB} = \frac{1}{2}\mathbf{AB} \). The position vector \( \mathbf{m} = \mathbf{OM} \) will be expressed as follows;

\[
\mathbf{OM} = \mathbf{OA} + \mathbf{AM} = \mathbf{OA} + \frac{1}{2}\mathbf{AB} = \mathbf{a} + \frac{1}{2}\mathbf{b} - \frac{1}{2}\mathbf{a} = \mathbf{a} + \frac{1}{2}\mathbf{b} - \frac{1}{2}\mathbf{a} = \frac{1}{2}\mathbf{a} + \frac{1}{2}\mathbf{b} = \frac{1}{2}(\mathbf{a} + \mathbf{b})
\]

Thus, the position vector \( \mathbf{m} = \mathbf{OM} = \frac{1}{2}(\mathbf{a} + \mathbf{b}) \). Point \( \mathbf{M} \) is called the midpoint of line \( \mathbf{AB} \).

b) In figure 10 above, \( \mathbf{A}(1,5), \mathbf{M}(6,7) \) and \( \mathbf{B}(11,9) \). Their position vectors are;

\[
\Rightarrow \mathbf{a} = \mathbf{OA} = \begin{pmatrix} 1 \\ 5 \end{pmatrix}, \quad \mathbf{m} = \mathbf{OM} = \begin{pmatrix} 6 \\ 7 \end{pmatrix} \text{ and } \mathbf{b} = \mathbf{OB} = \begin{pmatrix} 11 \\ 9 \end{pmatrix}
\]
Thus, \( m = OM = \frac{1}{2} \left\{ \begin{array}{c} 1 \\ 5 \end{array} \right\} + \left\{ \begin{array}{c} 11 \\ 9 \end{array} \right\} = \left\{ \begin{array}{c} 6 \\ 7 \end{array} \right\} \)

Thus, \( M(6,7) \)

In general, if \( A (a_1, a_2) \) and \( B (b_1, b_2) \), the midpoint of \( M \) of \( AB \) has coordinates; -

\[
M \left( \frac{a_1+b_1}{2}, \frac{a_2+b_2}{2} \right)
\]

Activity 12b

Given that \( A(a_1,b_1) \) and \( B(a_2, b_2) \), show that the coordinates of the midpoint of \( AB \) is \( M\left( \frac{a_1+a_2}{2}, \frac{b_1+b_2}{2} \right) \). (Pair & Share)

You may have come up with the following:-

\[
\begin{align*}
OA &= \left[ \begin{array}{c} a_1 \\ b_1 \end{array} \right] \quad \text{and} \quad OB = \left[ \begin{array}{c} a_2 \\ b_2 \end{array} \right] \quad \text{and} \quad AM = \frac{1}{2} AB.
OM &= OA + AM = OA + \frac{1}{2} AB. \quad \text{Thus,} \quad OM = \left[ \begin{array}{c} a_1 \\ b_1 \end{array} \right] + \frac{1}{2} \left[ \begin{array}{c} a_2 - a_1 \\ b_2 - b_1 \end{array} \right]
\Rightarrow OM &= \left[ \begin{array}{c} a_1 + \frac{1}{2}a_2 - \frac{1}{2}a_1 \\ b_1 + \frac{1}{2}b_2 - \frac{1}{2}b_1 \end{array} \right] = \left[ \begin{array}{c} \frac{1}{2}a_1 + \frac{1}{2}a_2 \\ \frac{1}{2}b_1 + \frac{1}{2}b_2 \end{array} \right]
\Rightarrow OM &= \frac{1}{2} \left[ \begin{array}{c} a_1 + a_2 \\ b_1 + b_2 \end{array} \right] = \left[ \begin{array}{c} \frac{a_1+a_2}{2} \\ \frac{b_1+b_2}{2} \end{array} \right]
\end{align*}
\]

Thus, the coordinates of the midpoint are \( M(\frac{a_1+a_2}{2}, \frac{b_1+b_2}{2}) \).
In the figure given above, all the points of triangle ABC have been moved in the same direction and by the same magnitude to triangle A'B'C'. The object triangle ABC is said to have undergone a translation. The translation vector \( \mathbf{T} = AA' = BB' = CC' \).

Thus, we can write the translation vector \( \mathbf{T} \) as:

\[
\mathbf{T} = \begin{pmatrix} 6 \\ -6 \end{pmatrix}
\]
Activity 13b

Find the image of the point $R(-4,5)$ under the translation $T$ given by:

$$T = \begin{pmatrix} 3 \\ -2 \end{pmatrix}$$

(Pair & Share)

You may have come up with the following:-

The image of $R$ will be $[3 + (-4), (-2) + 5] = [-1, 3] \Rightarrow R'(1, 3)$.

Activity 14 (Group Discussion)

(i) Study the sample ASEI lesson given below and identify the types of ‘inquiry based learning’ activities incorporated in the lesson & whether 5E Instructional model has been used

(ii) Suggest some improvements (Group discussion)

SAMPLE ASEI LESSON: - VECTORS

Subject: Mathematics

Time: 40 minutes Number of Students: 43

Topic: Vectors Sub-topic: Addition of vectors

Class: Form 2S

Rationale:

You use vectors in almost every activity you do. Everyday activities involve scenarios dealing with magnitude and direction. Examples include diaphragm muscles, walking to school and so on. Teachers and learners have a challenge in teaching & learning of vectors especially on vector representation, multiplication of a column vector by a scalar, ratio theorem especially on vectors involving external division and application of vectors in geometry among others. Thus, the need for teachers to design suitable teaching/learning activities in the topic of vectors

Objectives: By the end of the lesson the learner should be able to:-

1) Read and add drawn/directed vectors
2) Illustrate the sums of given drawn/directed vectors
3) Express vectors in column form
4) Calculate magnitude and direction of vectors
Pre-requisite knowledge:

Numbers, trigonometric ratios, fractions, Cartesian graph/grid, squares & square roots, common solids, construction of lines, etc.

Teaching/Learning resources:

Geometrical sets, rulers, graph papers, plane sheets, and pencils among others

References:

2) Macmillan Secondary Mathematics Book 2, Pg 253 – 254
3) Explore Mathematics, Longman Kenya, Pg 103 – 104 & 353 - 356
4) Advancing in mathematics Form 2, Longhorn, Kinyua Mugo, etal Pg 207 – 209

<table>
<thead>
<tr>
<th>Stage/Time</th>
<th>Teaching/Learning Activities</th>
<th>Teaching/Learning Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Learners are asked to do the following question:- Add the two vectors given below: -</td>
<td>(i) Laying the vectors 'head to tail' or 'nose to tail' in sequence to create a triangle – will give the resultant vector say c</td>
</tr>
<tr>
<td>(10min)</td>
<td>(Engaging)</td>
<td>(ii) Completion of a parallelogram and use of parallel lines to help draw the resultant vector say r</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td>a) Learners are given the following:-</td>
<td>✓ Expression of vector AF in some of the following ways</td>
</tr>
<tr>
<td>Step 1 (10min)</td>
<td>Learners are asked to express vector AF in several ways using the above diagram. (To discuss in pairs)</td>
<td>✓ The concept of ‘head to tail’ or ‘nose to tail’</td>
</tr>
<tr>
<td>(Exploring)</td>
<td>(Explaining)</td>
<td>AF = AB + BC + CF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AF = AH + HG + GH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AF = AC + CF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AF = AD + DF, etc</td>
</tr>
<tr>
<td>Step 2 (15min)</td>
<td>b) Learners are also given the following: -</td>
<td>✓ (i) PR (ii) PT (iii) QS (iv) TR (v) O (vi) RQ (vii) Cannot be expressed to a single vector (ix) O</td>
</tr>
<tr>
<td>(Elaboration)</td>
<td>(Evaluation)</td>
<td>✓ The concept of ‘head to tail’ or ‘nose to tail’ in sequence</td>
</tr>
</tbody>
</table>
Worksheet

1) Using the figure given below, illustrate the sums of the following vectors:
   - (i) $a + c$
   - (ii) $f + g$
   - (iii) $b + e$
   - (iv) $c + d$
   - (v) $h + j$
   - (vi) $a + b + d$
   - (vii) $c + g + j + h$

2) Relate column vectors of individual vectors to that of their sum

3) Design other vector sums
**Homework/Assignment**

1) Draw a triangle STR and put arrows on its sides to show \( TS + SR = TR \)

2) Draw quadrilateral ABCD and on it show BC, CD and DA. State a single vector equivalent to BC + CD + DA

3) Vectors \( \mathbf{a}, \mathbf{b}, \) and \( \mathbf{c} \) are such that \( \mathbf{a} = \mathbf{b} \) and \( \mathbf{b} = \mathbf{c} \). What can you say about \( \mathbf{a} \) and \( \mathbf{c} \)?

4) The diagram below shows a grid with three vectors \( \mathbf{a}, \mathbf{b} \) and \( \mathbf{c} \) drawn. Draw a similar grid and illustrate the following

   (i) \( \mathbf{a} + \mathbf{b} \) (ii) \( \mathbf{b} + \mathbf{c} \) (iii) \( \mathbf{a} + 2\mathbf{b} \) (iv) \( \mathbf{b} - \mathbf{c} \) (v) \( \mathbf{c} - 2\mathbf{a} \)

**Assessment Question (KCSE 2014 Paper 2 No 22)**

In the figure below, \( \mathbf{OA} = \mathbf{a} \) and \( \mathbf{OB} = \mathbf{b} \). M is the midpoint of OA and AN:NB = 2:1

![Diagram](image)

a) Express in terms of \( \mathbf{a} \) and \( \mathbf{b} \)

   (i) \( \mathbf{BA} \) (1 mark)
   (ii) \( \mathbf{BN} \) (1 mark)
   (iii) \( \mathbf{ON} \) (2 marks)

b) Given that \( \mathbf{BX} = h\mathbf{BM} \) and \( \mathbf{OX} = k\mathbf{ON} \), determine the values of \( h \) and \( k \) (6marks)

**Activity 15 (Group Discussion)**

- In groups of 4 or 5
  - a. Identify challenges in teaching & learning of Vectors
  - b. Develop teaching and learning activities that promote inquiry based learning using 5E instructional model

Prepare a 40 minutes ASEI lesson that incorporate the activities developed above for peer teaching

---

101
Conclusion
You have learnt about a few concepts to the topic of vectors and how to approach these concepts during teaching and learning. You have designed and discussed activities that incorporate inquiry based learning using the 5E instructional model to help learners grasp the concepts better. It is expected that you will employ the skills learnt to engage your learners fully during the teaching and learning of vectors. The sub-topics covered lay a firm foundation in subsequent sub-topics in higher levels of learning.

References
2) Macmillan Secondary Mathematics Book 2, Pg 251 – 262
3) Explore Mathematics, Longman Kenya, Pg 100 – 108 & 351 - 358
4) Advancing in mathematics Form 2, Longhorn, Kinyua Mugo, etal Pg 207 – 209
PHYSICS

Topic One: Particulate Nature of Matter

Introduction
Welcome to this section in which we shall apply the 5E instructional model in the teaching and learning of the topic particulate nature of matter. This will be done by designing teaching and learning activities that promote inquiry in science and implementing a live lesson in the classroom.

Rationale
According to a study in five African countries that sought to establish the impact of TCTP in the recipient countries carried out by CEMASTEA in 2015, the topic *Properties of matter* was identified as an area where teachers require further capacity building. Authentic learning occurs when learners are able to relate their learning to everyday ideas. Today’s learners have been said not to relate concepts in physics classrooms well to real-life phenomena.

This section provides you with an opportunity to design Inquiry-Based Learning activities that would ensure learners are involved in the teaching and learning process for an understanding of the concepts. The section will also accord you an opportunity to discuss and share good classroom practices in the teaching and learning of the topic. The emphasis will be on the use of the 5E instructional model incorporating activities that promote IBL.

Section goal
The goal of this section is to enhance your ability to effectively use the 5E instructional model in teaching and learning of the topic *Particulate nature of matter*.

Section Objectives
By the end of the section, you should be able to:
1. Design lesson activities that promote Inquiry-Based Learning,
2. Design a lesson plan based on the 5E instructional model,
3. Incorporate lesson activities that promote IBL into the 5E instructional model,
4. Appreciate the use of the 5E instructional model in the teaching and learning of physics.

Section outcome
Enhanced participants’ ability to use the 5E instructional model in teaching and learning

Historical background of particulate nature of matter
The ancient Greeks were the first people to come up with the idea that everything was made up of tiny particles. A rich philosopher called Democritus developed a theory of ‘atoms’. Democritus thought of his ‘atoms’ as having different shapes and sizes to explain the different properties of everyday materials. For example, water ‘atoms’ were thought to be smooth and round (because
water flows easily). But iron 'atoms', according to Democritus, were probably sharp and jagged (because iron is hard, so its atoms can't move past each other easily). An essential part of Democritus' theory was that these 'atoms' could not be broken up into still smaller particles (in fact, 'atom' comes from a Greek word meaning 'cannot be cut'). While some thinkers liked his ideas, many others did not believe this part of his theory, so people lost interest in the theory for many centuries.

Part of the problem, of course, was that nobody could see any of these particles. Atoms are far too small for that! And that is still true today, although we now have very powerful machines that enable us to see images that correspond to particles. A new industry is being developed, called 'nanotechnology' that uses the latest scientific instruments to move even single atoms around and position them precisely.

Look at the image of the man below. It is made using molecules of carbon monoxide.

*Image produced by electron scanning probe*

**Activities to demonstrate inquiry based learning**

In activity 1, you will review the four levels of IBL.

<table>
<thead>
<tr>
<th>Activity 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giving reasons, classify the sample teaching-learning activities (a-d) below into the various IBL levels</td>
</tr>
</tbody>
</table>
a) Do gases undergo diffusion?

**Procedure**

i) Set up a transparent cylindrical tube on a table as shown in figure below.

![Diagram of a transparent cylindrical tube with cotton wool containing ammonium water and hydrochloric acid at the ends.](image)

ii) Put cotton wool containing ammonium water on one end and cotton wool dipped in hydrochloric acid on the other end.

iii) Wait for some time and make your observations.

iv) Explain your observations.

**Observations**

It is observed that white ring forms near the middle of the transparent tube.

**Explanation**

This is because the gas molecules of ammonia and hydrogen chloride diffuse and meet near the middle. When the two kinds of gases react, a solid of ammonium chloride is made. This looks like white smoke to our eyes.

b) What happens when a jar is inverted on top of a similar one containing bromine gas as shown in figure blow?

**Procedure**

i) Set up the apparatus as shown below.

![Diagram of a jar with bromine vapor.](image)
ii) Wait for some time and make your observations.

iii) What do you observe?

iv) Explain your observations

c) Do different gases diffuse at the same rate? Carry out an investigation.

d) The way to my village home is panoramic except for the foul smell around a factory that manufactures paper situated not far from the main road. In addition, other effects such as rusty iron roofs have been reported. I have noted that there is a problem that must be investigated and addressed.

Evidence that matter is made up of small particles

Activity 2
As scientists, design and try out IBL activities that could be used to demonstrate that matter is made up of small particles.

Activity 3
Using the materials and apparatus provided design and carry out activities to show that matter is particulate in nature. The activities should be designed in such a way that they promote IBL.

1. Pieces of paper, a pair of scissors and a magnifying glass
2. Sugar crystals, razor blade and magnifying glass
3. Measuring cylinder, potassium permanganate crystal, water, stirring rod
4. A strongly scented spray

Activity 4
Study the Sample ASEI lesson plan and identify the elements of the 5E instructional model.
Sample ASEI Lesson plan based on 5E instructional model

**Topic**: Particulate nature of matter

**Sub-Topic**: Diffusion

**Date**: 02/09/2017

**Class**: Form 1S

**Time**: 2:30 -3:10 Pm

**Duration**: 40 Min.

**Rationale**
Understanding of the behavior of solids, liquids and gases under different physical and chemical conditions is important in order to avoid accidents that would otherwise occur and cause loss of lives. The study of particulate nature of matter lays a foundation for the learners to understand the behavior of matter in its various states.

**Pre-requisite knowledge and skills**
- The three states of matter namely: solid, liquid and gas
- How the particles in each of the states are arranged
- Observation, manipulative and recording skills among others

**References**


**Objectives**
By the end of the lesson, the learner should be able to:
- Define Diffusion
- Explain diffusion in liquids
<table>
<thead>
<tr>
<th>Stage</th>
<th>T/L Activity</th>
<th>Learning points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>The previous lesson is reviewed through question and answer method.</td>
<td>1. Solid, liquid and gas</td>
</tr>
<tr>
<td>5 Min.</td>
<td>1. Name three states of matter</td>
<td>2. Solid has a fixed volume and a definite shape.</td>
</tr>
<tr>
<td></td>
<td>2. Describe the three states of matter</td>
<td>The liquid has a fixed volume, but has no definite shape and flows easily.</td>
</tr>
<tr>
<td></td>
<td>3. Suppose you add a few drops of dirty water into 500mls of clean water.</td>
<td>Gas fills the space of the container in which it is placed.</td>
</tr>
<tr>
<td></td>
<td>What will be observed? Explain your observation</td>
<td>3. The dirty water mixes with the clean water</td>
</tr>
<tr>
<td><strong>Step 1 (5 Min)</strong></td>
<td>• Pause the key question: How would you explain the process of dirty water mixing with clean water?</td>
<td>The mixing is as a result of movement of particles</td>
</tr>
<tr>
<td></td>
<td>• Let the learners carry out the activity in the worksheet using the materials provided.</td>
<td>• Initially the drop of Potassium Permanganate is seen at the bottom of the boiling tube.</td>
</tr>
<tr>
<td></td>
<td>• After carrying out the activity ask learners to explain their observations (minds-on activity)</td>
<td>• However after sometime, the purple colour of potassiumpermanganate fills up the entire boiling tube</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Diffusion has taken place in the liquid. The tiny particles of potassiumpermanganate have</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Spread throughout the water in the boiling tube.</td>
</tr>
<tr>
<td><strong>Step 3 (5 Min)</strong></td>
<td>Ask learners to describe one application of the phenomena of diffusion in everyday life</td>
<td></td>
</tr>
<tr>
<td><strong>5 minutes Conclusion</strong></td>
<td>Teacher to wrap up from the observations made in the groups’ activities by Consolidating and harmonizing scientific concepts</td>
<td>• Diffusion is the process by which tiny particles spread from regions of high concentration to those of low concentration</td>
</tr>
<tr>
<td></td>
<td>Ask learners to:</td>
<td>• The occurrence of diffusion proves that potassiumpermanganate (VII) consist of tiny and discrete particles. This experiment demonstrates diffusion in liquids.</td>
</tr>
<tr>
<td></td>
<td>• Define diffusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Explain diffusion</td>
<td></td>
</tr>
<tr>
<td><strong>5 minutes Evaluation</strong></td>
<td>Ask learners to answer question 6 in the worksheet)</td>
<td>The higher temperature of the water will make the tiny particles of which water is made up of move faster which in turn will increase the rate at which the particles of potassiumpermanganate spread.</td>
</tr>
</tbody>
</table>
STUDENT'S WORKSHEET
Sub-topic: Diffusion
Activity
You are provided with the following:
Boiling tube, water, potassium permanganate solution, dropper
1. Half fill the boiling tube with water
2. Using a dropper, place one drop of potassium permanganate at the bottom of the boiling tube as shown in figure below

![Diagram of a boiling tube with a dropper and potassium permanganate solution](image)

3. What do you observe after sometime?
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………

4. Explain your observations
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………

5. Describe one application of the phenomena in (4) above in everyday life.
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………

6. What would be observed if the temperature of the water in the boiling tube is increased?
   Explain the observations.
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………………………
Sample assessment questions

1. Using pollen grains placed in water, explain how their motion supports the idea that matter is not continuous.
2. How does temperature affect rate of diffusion?
3. In the figure below, ammonia gas, which is acidic diffuse and react to form a white deposit on the walls of the glass tube. The deposit forms nearer end B.

![Diagram of gas diffusion]

a) Which gas diffused faster?
b) How does the rate of diffusion depend on the mass of gas particles?
c) If the experiment was performed at a higher temperature, would you expect it to take longer or shorter time to form the white deposits? Explain.

Activity 4
The table below shows the concepts covered under the topic *particulate nature of matter* in the Kenyan syllabus. Prepare a 40 minutes lesson based on the 5E instructional model. One of you will peer teach while others observe. You will then have a panel discussion to critique and improve on the lesson.

Table below Content areas in the topic *particulate nature of matter* taught at form 1 level in Kenya

<table>
<thead>
<tr>
<th>Specific objective</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Give evidence that matter is made up of tiny particles</td>
<td>Experiments to show that matter is made up of tiny particles (e.g. cutting papers into small pieces, dilution experiments etc.)</td>
</tr>
<tr>
<td>2. Describe experiments to show that particles of matter are in constant random motion</td>
<td>Brownian motion</td>
</tr>
<tr>
<td>3. Explain the states of matter in terms of particle movement</td>
<td>States of matter</td>
</tr>
<tr>
<td>4. Explain diffusion</td>
<td>Diffusion (Graham’s law not required</td>
</tr>
</tbody>
</table>
Conclusion

In this section, we have discussed and demonstrated Inquiry-Based Learning activities in the topic particulate nature of matter and incorporated them in the 5E instructional model. It is hoped that you will apply the knowledge and skills acquired therein in your teaching when you go back to your country.

The inquiry is a critical component of a science program at all grade levels and in every domain of science, and designers of curricula and programs must be sure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry. Students then will learn science in a way that reflects how science actually works.

References


Topic Two: Linear motion

Introduction
Welcome to this session in which you will further explore the use of IBL in the teaching and learning of Physics using the topic; Linear Motion. More specifically, you will explore the Inquiry- Based Learning using the 5E instructional model. In order to study the nature of linear motion you will need to design a variety of experiments to make it easier for students to understand the concepts involved in motion and the factors affecting it. You will have an opportunity to discuss and share best practices in the use of the 5E instructional model of IBL in the teaching and learning of physics in your countries and schools.

Rationale
From CEMASTEA, TNA report of 2015, it was found that teachers rarely link concepts in this topic to real life situations. Further, the study revealed that learners were rarely given a chance to make investigations on the relationships between distance, time, displacement, speed, velocity, acceleration and acceleration due to gravity. In this course, we will develop activities that will make the learner, not only understand concepts, but appreciate the relevance of what is learnt in the classroom to the day-to-day life. During this session, IBL activities will be designed and carried out. Also, you will develop and implement lessons that incorporate 5E instructional model in order to make learning enjoyable.

Section Goal
The goal of this section is to enhance your ability to use IBL strategies in the 5E instructional model in your teaching of linear motion.

Session Objectives
By the end of the session, you should be able to:
1. Design and carry out activities that incorporate Inquiry- Based Learning activities in the topic of Linear Motion,
2. Develop an ASEI lesson that incorporates Inquiry- Based Learning using the 5E instructional model and peer teaching.
3. Appreciate the 5E instructional model

Learning outcome
Enhanced participant’s ability to use the 5E instructional model in teaching and learning.
Session Content

Table below shows the syllabus statement for the topic on linear motion (as used in Kenyan secondary schools)

<table>
<thead>
<tr>
<th>Objectives; By the end of this topic, the learners should be able to:</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define distance, displacement, speed, velocity and acceleration.</td>
<td>Distance, displacement, speed, velocity, acceleration (Experimental treatment required)</td>
</tr>
<tr>
<td>Describe experiments to determine velocity and acceleration.</td>
<td>As above</td>
</tr>
<tr>
<td>Determine acceleration due to gravity</td>
<td>Acceleration due to gravity.</td>
</tr>
<tr>
<td>• Free fall</td>
<td></td>
</tr>
<tr>
<td>• Simple pendulum method</td>
<td></td>
</tr>
<tr>
<td>Plot and explain motion-time graphs</td>
<td>Motion-time graphs</td>
</tr>
<tr>
<td>• Displacement-time graphs</td>
<td></td>
</tr>
<tr>
<td>• Velocity-time graphs</td>
<td></td>
</tr>
<tr>
<td>Apply the equations of uniformly accelerated motion.</td>
<td>Equations of uniformly accelerated motion</td>
</tr>
<tr>
<td>Solve numerical problems</td>
<td>Problems of uniformly accelerated motion</td>
</tr>
</tbody>
</table>

In the activities that follow, your skills to incorporate the 5E model in IBL in ASEI lessons will be enhanced.

Activity 1: Basics terms in linear motion

Describe a short activity that uses IBL to relate the following terms:

a) Distance and Displacement
b) Speed and Velocity
c) Velocity and acceleration

Levels of IBL

Examples of activities in linear motion that incorporate various levels of IBL

1. Confirmatory Inquiry
   In determining the value of acceleration due to gravity, ‘g’, using the simple pendulum method, give the required materials, the procedure, instructions, including the formula and expected value of ‘g’.

2. Structured Inquiry
   In determining the value of g using the simple pendulum method, give the required materials, the procedure and ask them to determine the value of ‘g’
3. **Guided Inquiry**
Determine the value of ‘g’ using the simple pendulum method.

4. **Open Inquiry**
Determine the value of ‘g’.

**Activity 2: A video on determining ‘g’ using the ticker timer**
Observe the video clip on determining the acceleration of freefall by using the ticker timer provided and share in plenary your observations. The video is available on a CD provided.

**Designing Lesson activities using IBL**

| Activity 3: | For each level of IBL, design an activity for any concept of linear motion (Use the syllabus statement). |

**Hands on Activities**
**Activities on IBL: Identification of conventional/alternative apparatus for experiments/activities**
The following activities relate to the topic of linear motion. Perform them as accurately as possible, then record and explain the observations made. One of the activities has been done as an example. You are advised to carry out the activity.

**Investigating free fall**

<table>
<thead>
<tr>
<th>Activity 4:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Design a guided IBL activity that learners will use to investigate the motion of three free falling objects with varied masses. What factors will be under investigation in this motion?</td>
</tr>
<tr>
<td>b) Carry out the activity in a) above.</td>
</tr>
</tbody>
</table>

**Carrying out IBL activities**

<table>
<thead>
<tr>
<th>Activities 5 – 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>In groups, carry out the activities as indicated below.</td>
</tr>
</tbody>
</table>
Activity 5: Motion of a falling object

Arrange apparatus as shown in the figure below and investigate the motion of a tennis ball falling from a height of about 2 meters.

Ticker tape timer set up

a) Make your observations.
b) What does the tape chart tell you about the motions of the falling mass?
c) Using the dots on the tape, determine the value of ‘g’.
d) Comment on the value of ‘g’ obtained.
e) Which level of IBL is this activity?
Activity 6: Vertical and Horizontal motion

Set up a ruler and two similar coins as shown below.

Predict what would happen to the two coins as they fall.

Press on the ruler and tap one end so that A falls vertically while B is projected sideways.

Listen to the coins hitting the ground.

Explain your observations.

What level of IBL is this activity? Justify your answer.

Figure 2: Vertical and horizontal motion

Developing an IBL Based activity

Activity 7:

a) In your groups, develop either a guided or open Inquiry Based learning activity in any concept on the topic of linear motion.

b) Make a practical presentation of the activity above to the other groups in plenary

Critiquing of a sample ASEI Lesson plan

Activity 8:

In groups, study the sample ASEI lesson plan below and answer the question below it.
A SAMPLE ASEI LESSON PLAN

TOPIC: LINEAR MOTION

SUB-TOPIC: VELOCITY TIME GRAPH

CLASS: FORM 3

DURATION: 40 MINUTES

Materials required: Graph papers, geometrical sets and calculator

Pre-requisite knowledge and skills: Velocity, distance speed and graphical skills

Reference: Secondary Physics Form 3 pupils Book, KLB

Lesson objectives: By the end of the lesson, the learner should be able to:

a) Plot velocity – time graph
b) Explain velocity – time graph

Rationale

In their daily lives, we experience or observe motion of bodies such as persons, vehicles and animals. Motion of bodies can be expressed graphically yet the students are unable to attach meaning to these graphs. This therefore gives the need to develop the skills

<table>
<thead>
<tr>
<th>Stage/Time</th>
<th>Learning/teaching activities</th>
<th>Learning point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Define velocity and acceleration</td>
<td>$\Delta$ in displacement per unit time $\Delta$ of velocity with time</td>
</tr>
<tr>
<td>5 minutes</td>
<td>Describe the motion of the object at each part on the two different graphs in Q1 of the worksheet provided</td>
<td></td>
</tr>
</tbody>
</table>

| Development       | Learners explore the example of a motion Story: “The Hungry Bug”(See worksheet)           | Constant and accelerated motion                      |
| 30 minutes        | Learners create and explore various motion graphs                                           |                                                    |
|                   | In groups, learners create a motion graph story displaying constant and accelerated motion as in Q2 of the worksheet |                                                    |
|                   | Each group explain the motion graph in terms of velocity and acceleration                  |                                                    |
|                   | Terms harmonizes the understanding of the motion graphs                                    |                                                    |

| Evaluation and conclusion | 1. Straight line represent uniform acceleration                      | m/s² |
| 5 minutes                | 2. What does the velocity – time graph represent                  |      |
|                         | 3. SI unit of acceleration                                     |      |
Worksheet

1. Describe the motion of the object at each part on the two different graphs.

2. In your groups, create a motion graph story displaying constant and accelerated motion. Then use illustrations to present the motion. Refer to the example below in carrying out the activity.

The illustrations should have
i. At least 5 different motions
   • At least 2 constant velocity
   • At least 2 accelerated motion

ii. Each motion must have
   • Displacement vs. time graph
   • Velocity vs. time graph

Example of a motion Story: “The Hungry Bug”
Darcy the lady bug was a happy little bug. One day, she decided to take a walk to the nearby park. She left her home and crawled at a calm, constant pace. She then slowed down to a stop and sat on a park bench to enjoy the sun. She remained there and enjoyed her lunch for most of the afternoon. After she was finished, she remembered she had an appointment to meet her friend Lucky. She calmly walked back to her home and then quickly sped off away from her home until she came to a rest at her friend’s house.
Group Task

From the above sample ASEI lesson plan, identify elements of IBL and suggest how it can be modified to enhance the teaching and learning of free fall.

Activity 9: ASEI Lesson planning and Peer teaching

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>Prepare a 40 minute ASEI lesson in any one of the concepts in the topic of linear motion that incorporates IBL using the 5E instructional model</td>
</tr>
<tr>
<td>b)</td>
<td>Conduct a peer teaching session where one of you will teach while others observe.</td>
</tr>
<tr>
<td>c)</td>
<td>Critique the lesson observed</td>
</tr>
</tbody>
</table>

References

1. KIE, Secondary Physics, Form 3 Pupil’s Book,
3. Tom Duncan, GCSE Physics, 3rd Edition, John Murray, p.129
UNIT FIVE: LESSON OBSERVATION

Introduction
Welcome to this unit on lesson observation. Lesson observation focuses on improvement of teachers’ classroom instruction through a collection of data on what the teacher and learners do during the teaching-learning process. It involves direct face-to-face interaction between the observer(s), the teacher and the learners where the observers examine actual behaviors of the learners and teachers as the lesson is implemented; collect data and analyze it for purposes of improving instruction. This session is aimed at enhancing your ability to monitor learning through lesson observation, data collection and conduct post-lesson discussion and evaluation in order to improve your lessons and classroom practices.

Rationale
Learning from the experiences of others is one-way teachers can reflect on own classroom practices with the aim of improving teaching and learning. This may be achieved through the opportunity to observe lessons developed and implemented by their peers or being observed by their peers. The training report for teachers and educators from SMASE WECSA countries indicated that the teachers required training in lesson observation, analysis and evaluation (CEMASTEA, 2015). In addition, the findings of a study conducted by CEMASTEA in five SMASE-WECSA countries (Malawi, Rwanda, Ethiopia, Nigeria and Ghana) indicated that teachers and trainers needed capacity building on lesson observation (CEMASTEA, 2016). It is, therefore, important for teachers and INSET providers to acquire lesson observation, analysis, and skills and use the outcomes to make pedagogical judgments. This session is therefore aimed at enhancing the participant’s ability to monitor learning through lesson observation, data collection and conduct post-lesson evaluation in order to improve their lessons and classroom practices.

Objectives: By the end of the unit, you should be able to:
1. Describe the meaning and purpose of lesson observation
2. Plan and implement lesson observation in Inquiry-Based Learning
3. Use lesson observation, reporting resources that facilitate the process of lesson observation in Inquiry Based Learning
4. Analyse data from the observed lesson and make recommendations for lesson improvement

Expected outcome
The course participants are able to demonstrate skills for lesson observation, analysis and evaluation in Inquiry-Based Learning
Concept, meaning and purpose of peer lesson observation

Activity One
Have you experienced lesson observation (as an observer or being observed) what was the purpose of that lesson observation and how was the experience? What was your role during the lesson?

You may have come up with the following:

- Lesson observation is an activity in which teachers may jointly plan a lesson together and one of them implements it while others observe.
- It may also involve a teacher inviting other teachers to give feedback on his or her lesson.
- Observers use data obtained from a lesson and provide feedback to the teacher for the purpose of improving his or her practice.
- Peer Lesson Observation is a strategy of raising standards of teaching and learning provided that teachers are empowered on how to go about the process.

Activity Two
What do you think is your role during an observation of an IBL lesson observation?

Possible responses

Listen keenly to hear
- What the teacher says
- What the learner says
- How they say it

Look carefully to see
- What the teacher is doing
- What the learners are doing
- How they are doing it

Write down your observations
- Accurate record of what you observe
- Reference for post-lesson discussion
- Future reference
**Process of Lesson Observation**

Lesson observation is one of the most powerful strategies to raise standards of teaching and learning. It is a process by which teachers observe each other’s lessons, collect evidence and provide feedback to colleagues about their teaching efforts and practices. It is a way of thinking back on the lesson and considering answers to questions such as:

- What went well in this lesson? Why?
- What challenges were experienced? Why?
- What could have been done differently?
- What lessons are learnt from this experience?

**Why do you think lesson observation is important?**

- Provides opportunities to discuss challenges and successes with trusted colleagues
- Supports sharing of ideas and expertise among teachers
- Builds a community of trust through opening classroom practice to a wider audience
- Encourages openness and sharing of practice with a focus on improving impact on learning
- Develops a deeper understanding of one’s professional practice
- Acknowledges diverse ways of engaging in classroom/leadership practices
- Fosters the character of continuous improvement
- Other ideas

---

**Process of Lesson Observation/Observation**

**Stage One: Pre-Observation meeting**

**During this:**

a. Provide the background and context of the lesson to be observed (lesson objectives, concepts, skills, problem to be addressed)

b. Identify focus of the observation (what to observe in the lesson)

c. Familiarize all participants with the observation tool

d. Define roles of the teacher and observers

e. Agree on date, time and duration of the observation.

During this stage, it is important to ensure that you clearly understand the structure of the lesson. This will help you track learning as well as notice when the teacher makes critical teaching decisions that were not in the lesson plan.
Effective observer

- Agrees to attend/invitation
- Knows what the lesson is about and could have a copy of the lesson plan
- Knows the teacher and objectives for the lesson
- Is briefed about the learners and the learning environment (class, laboratory or outdoor)
- Understands how the teacher has defined his/her role for the lesson to be observed.
- Learns the teachers’ expectations for what will actually happen in the lesson observed.
- Carries some writing materials

Effective teacher

- Prepares adequately including preparing the materials and try out activities and anticipates learners responses
- Sets the teaching environment including alerting the learners
- Open-minded – a desire to listen to more sides than one; the possibility of error even in beliefs dear to them.

Stage Two: Lesson Observation

- During lesson implementation, evidence/data related to the already discussed learning goals is gathered.
- Observers take notes and include taking focus on the entire class, learning groups and specific students. This could include learner’s activities, their perceived thinking, and behaviors. In our case, for example, the focus in more on evidence on inquiry-based learning and the implementation of a 5E instructional model.
- During the lesson, observers observe and describe the nature and quality of the lesson and indicate supporting evidence. Note and briefly describe specific examples or quotes to authenticate their evidence

During this stage, ensure that:

- You stay far enough so that you do not obstruct the communication between the teacher and students.
- Stay close enough to notice the students’ working or discussing.
- Remember teaching involves rapidly changing teaching decisions that you need to notice.
- The goal of the observation is not to find teaching mistakes but rather to observe learning opportunities that the teacher provides or misses.
- Focus more on how the learners are interacting with the teacher, with each other and with the task at hand and how teacher activities are supporting learning.
Stage Three: Post lesson Discussion: Lesson analysis

- After the lesson you can, together with the teacher who implemented the lesson hold a brief session to reflect on the lesson. Though there is no uniform procedure for debriefing, it is usually wise to have a discussion leader and someone to document the proceeding.
- The session is structured to maximize the richness of the evidence while minimizing personalized feelings with a more focus on the learning rather than teaching.
- The teacher who delivered the lesson is allowed to speak first. They, in an independent self-analysis, make comments or self-observations on what actually occurred during the lesson; what worked, what did not work, what she/he thinks could be changed.
  - They could identify strength patterns. They as much as possible attempt to identify specific instructional acts that resulted in the desired outcomes.
- After this, peers share their evidence (comments, observations, and data) on the lesson with the focus being more on learner learning rather than the teacher.
  - The observers give their observational data and identify the cause and effect situations they recorded. Such could be labeled as decisions and actions made by the teacher and probable effect on the learners. These decisions or actions are divided into the categories that were agreed upon in the pre-observation conference. In our case, the inquiry methods of teaching would take center stage.
  - Be specific in your comments and questions.
  - Do not be evaluative in your feedback but describe lesson outcomes without attaching a ‘value labels’ to them.
  - You can also help the teacher understand how they can use the feedback.
  - The teacher receiving feedback listens carefully and does not justify or defend their actions in class.

Note
To remove the peer-observers power relationships, the end product of lesson observation should be a consensus between the teacher who implemented the lesson and the peers who observed the lesson. However, peers should not be reluctant to point our unsuccessful lessons and ineffective strategies; if not highlighted there would be no progress.

Lesson Observation Tools

| i. | List down important indicators /evidence/activities in a good IBL lesson? |
| ii. | Use these indicators to develop a lesson observation tool |

You may have come up with the following:

In a good IBL lesson, one may observe the following:
- a. stimulates introduction that arouse learners curiosity
- b. Learners formulate their own inquiry question.
- c. Learners collect information that helps them answer their questions.
- d. Learners connect information/knowledge they know and the data gathered to construct new knowledge.
e. Learners share/communicate their ideas with each other.
f. Learners have their experiences during and after the investigation

Other ideas

Practice of Lesson Observation and Post Lesson Discussion

Activity 7
In this activity, you will apply the skills of Lesson Observation you have learned to observe a short video lesson, collect some data/evidence of IBL and 5E instructional model and use it for post lesson discussion.

Ideas for Lesson Observation and Post Lesson Discussion

Teacher activities

Engagement: Lesson initiation: How did the teacher initiate the lesson?
- Did they give a stimulating introductory talk to arouse student’s interest?
- Is there a key question? An activity. How effective are these activities?
- Did they probe/link the student’s initial previous knowledge, ideas and skills?
- Are learners given the opportunity to formulate their own questions?

Teaching strategy: evidence of the level of inquiry:
- Level of inquiry: How was the inquiry activity designed, was it challenging but still manageable, are the inquiry activities sequenced in a logical order; do the activity arouse students’ thinking and creativity during the inquiry process?
- Is the questioning varied targeting both low order, and higher order thinking; what of their distribution, language, wait time, focus for questions (content, process); gender?
- Is there evidence to integrate teaching approaches or techniques (questioning, problem-solving, open-ended investigation discussion or group work) that engage learners in exploring real-world issues and solving problems?
- Are learning materials/resources appropriate and relevant?; are learners able to manipulate/exploit them to experience learning both as individual and in groups?
- Is the teacher the source of the knowledge (sage on the stage) or a learning facilitator (guide by the side) in the inquiry process?
- Is the language of instruction clear and level appropriate?
- Do teacher explanations and guidance actively encouraged/scaffold learners to take responsibility of their learning?
Others ideas
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Learner activities

  o Do/Did learners
    o Freely express themselves to the teacher and to each other?
    o Show excitement in the inquiry activities?
    o Design parts of their own investigations
    o Exercise and learn science and mathematics process skills?
    o Collect data, information; measure; record; predict, tell/discuss, observe
  o Explaining /communication. Are learners telling others, discussion, sharing, were learners able to share and discuss their science and mathematical ideas with each other; redesign their group activities, compare notes, write down their ideas and make conclusions, were learners excited about communicating their findings?
  o **Explaining**: Are learners able to merge information, make links from teacher guidance/facilitation to create new knowledge through reporting (individual and group
  o **Elaboration**: do you notice creation of new ideas/conclusions from their inquiry on their own?
  o What evidence from the lesson shows incidences of learning?
  o Did the learners have “eureka” moments during the inquiry? Evidence?

Other ideas
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
### Sample 5E Model lesson observation tool for Inquiry Based Learning

<table>
<thead>
<tr>
<th>Lesson Stage</th>
<th>What the teacher is doing (How is it an evidence of inquiry?) What do you see what do you hear?</th>
<th>What learners are doing (How is it an evidence of inquiry?) What do you see what do you hear?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engagement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elaborate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Adapted from:**

1. AKU-IED/SESEA Project, 2015. Lesson observation protocol

**Peer Lesson Observation and Observation Report**
Subject:

Teaching Group:

What were the most positive aspects of the lesson? (Give examples / cite evidence)

How do we know that learning objectives and success criteria were met and that all learners made progress in their learning? (Give examples / cite evidence) e.g. Questions/answers, perusing/markng pupil’s work, pupil self-assessment, peer assessment, etc

What would need to be done differently if the lesson were repeated? Activity timings, pupil groupings, use ICT etc.


Note
Over and above the data above what was agreed there are some other universal components of lessons that must remain a constant during lesson implementation and for which peers could take short notes on. Such could include
- Gender and equality responsive pedagogy in the classroom
- Infusion of emerging issues such as environmental, civic consciousness, health issues in activities and examples
- Classroom and the management of the learning environment
- ICT integration
Conclusion
Lesson observation is an important pedagogical practice that will assist you to become a better teacher. Evaluating your own teaching through observation and post-lesson discussions enables you to identify the strong aspects of your practice, as well as the weaknesses or points of growth that you may need to be adjusted or improved. If you form a tradition of looking back at all lessons you teach, through lesson observation and feedback, you will eventually develop a better understanding of the teaching processes (about instructional methods; where and when they work best, about teaching and learning resources, about learners, about classroom organization and management etc). Lesson observation will open you to the possibility that there is always a better or another alternative to doing something.

Final Reflection
- How does lesson observation and post lesson discussion help you become a better teacher?
- In what specific ways will your classroom practice be different?
UNIT FIVE: EFFECTIVE IMPLEMENTATION ON INQUIRY BASED LEARNING

Rationale
Effective implementation of inquiry based learning (IBL) is dependent on the teacher’s ability to facilitate the learners to raise appropriate and challenging questions that will guide them during their inquiry process, and trigger learner-generated investigations and learning. This session will give you an opportunity to explore strategies that you may need to consider in adapting knowledge and skill on the use of IBL and the 5E-instructional model.

Goal
The goal of this unit is effective implementation of IBL using the 5E-instructional model

Unit Objectives
1. Identify issues that promote or hinder effective implementation of IBL
2. Identify strategies for effective implementation of IBL using the 5E instructional model

Learning Outcomes
Effective implementation of IBL using the 5E instructional model

Activity
Reflect on your experiences during the training (general and subject sessions, and implementation of the lessons in Kenyan schools), focusing on how you may adapt IBL and the 5E instructional model in your respective countries.

a) What are the strengths of IBL and the 5E instructional model compared to your current practice

b) Discuss aspects that may hinder effective implementation of IBL using the 5E instructional model. You may consider the following:
   - Large classes
   - Available resources
   - Stakeholders involvement
   - Balance between examinations and acquisition of mathematical and scientific skills

c) How can the hindrances be overcome?
Implementation of IBL in Large Classes

A “large” class is less defined by form (size) and more defined by function (action); that is, a class is “large” when it becomes challenging to engage individual learners. Strategies that may be used to effectively involve learners in a large class include:

i) Questioning skills through exercises that require learner participation can help address this challenge. The question or exercise can take several forms

- Think-pair-share is where an instructor poses a question or problem to the class and after giving learners time to consider their response (think), the learners are asked to partner with another learner to discuss their responses (pair). Pairs of learners can then be asked to report their discussions to larger groups (Angelo & Cross, 1993)

- Minute papers where learners are asked to spend one to three minutes writing the main point of the lesson as well as questions that remain. This serves as a formative assessment promotes and helps learners to consider what they do and don’t understand.

ii) Organizing learners into smaller-manageable groups of about 8-10 members. Small group learning is one of the most reliable approaches to promote active learning in large classes. It refers to a situation where a teacher divides learners into smaller manageable numbers for effective learning. This is the best approach to use where each learner has a chance to learn practically. It can be tailored to meet the unique needs of each learner. Benefits from use of this strategy may include:

- Small group learning promotes individual participation where students learn at their own-pace. It also helps in promoting teamwork and sharing of experiences. Through this, students develop positive attitudes towards helping each other thus making learning more interesting and participatory.

- Small group learning is ideal for project work because it promotes the development of independent habits and self-study skills. However, small group learning is not without its challenges.

- Working in small groups promotes self-esteem and confidence in the learners. It is common to find children who rarely contribute in class, making valuable contribution and suggestions during group work.

- Small group learning enhances and promotes personality traits such as honesty, tolerance, humility, self-control, fair play, patience and leadership among learners.
CONCLUDING UNIT: ACTION PLANNING

Introduction
Welcome to last unit of this module. You have been taken through the training and our expectations are that you have gained skills and knowledge on IBL and 5E instructional model and that you are capable of implementing such training back in your countries. You are expected to prepare an action plan detailing how you will organize a stakeholders/feedback workshop to sensitize others on the benefits of this training.

Rationale
It is our expectation that you will cascade the training content to mathematics and science teachers in your countries. The participants will prepare a programme plan for implementation of the training in their countries. This session accords the participants an opportunity to prepare an action plan for implementation of the training in their countries.

Objectives
Participants are expected to
1. Develop an action plan for implementation of the training programme
2. Present them a for use during programme implementation

Discussion Tasks
1. Use the training program to draw a program for the workshop
2. Develop an action plan for implementation of activities (use template below)
3. Make a presentation to others using a gallery tour as you explain to colleagues about your action
4. Use feedback from your peers to improve your plan.
Third Country Training Programme 2017

Improving the Quality of Science and Mathematics Education; through Inquiry Based Learning and Peer Lesson Evaluation

Action Plan for Experience Sharing SEMINAR

Name of Country __________________________

Names of members

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Goals

1. Goal I:
2. Goal I:
3. Goal I:
### Action Planning Template

<table>
<thead>
<tr>
<th>Actions Steps and Possible Datelines</th>
<th>Objectives(s) and expected outputs of activities and actions</th>
<th>Person(s) Responsible Facilitators and Participants</th>
<th>Resources Required including budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>What needs to be done?</td>
<td>What are the expected outcomes of the activity</td>
<td>Who should take action to complete this step?</td>
<td>What do you need in order to complete this step?</td>
</tr>
<tr>
<td>When should this step be completed?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Planning Meeting for workshop | Allocate duties | Participant to this training | |
| Check preparations for INSET | | | |

### Are there any potential challenges that may impede completion? How will you overcome them? What are the assumptions?

**Potential challenges**

**Assumptions**

**General remarks (optional):**
VISION
A CENTRE OF EXCELLENCE IN TEACHER CAPACITY DEVELOPMENT IN AFRICA

MISSION: TO TRANSFORM TEACHING BY CONTINUOUSLY DEVELOPING COMPETENCIES FOR EFFECTIVE CURRICULUM DELIVERY AND IMPROVED QUALITY OF EDUCATION

KENYA VISION 2030