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PRACTITIONERS JOURNAL OF TEACHERS IN STEM EDUCATION (PJTSE)

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About the Journal

Practitioners Journal of Teachers in STEM Education (PJTSE) is a publication of the Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA). It is a Journal for teachers and by teachers that aims at publishing original work in the form of theories, research, models, and experiences that teachers can draw from to support curriculum implementation and improve practice in Science, Technology, Engineering and Mathematics (STEM). This is in line with the aspirations inherent in the Kenya Vision 2030, particularly in the Education and Training sector of the Social Pillar.

The importance of STEM education in today's rapidly evolving world cannot be overstated. STEM disciplines shape how we live and interact with our environment and fuel innovation and progress. The CEMASTEA Practitioner Journal of Mathematics and Science Teachers (PJTSE) proudly present a platform for sharing STEM research and classroom practices. The journal also provides teachers a platform to connect with colleagues from different schools and regions, fostering community and collaboration within the education sector.

STEM research is a gateway to understanding and addressing the most pressing challenges of our time. Through investigation and inventive thinking, STEM researchers unravel the mysteries of the universe, create groundbreaking technologies, and drive economic growth. This Journal celebrates the tireless efforts of teachers and teacher trainers who explore uncharted territories and redefine the boundaries of human knowledge in STEM education.

PJTSE is a peer-reviewed journal that employs a double-blind review process. The following editorial Board members and technical officers support publishing the PJTSE.

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Editorial

Welcome to the Practitioners Journal of Teachers in STEM Education (PJTSE). Initiated by CEMASTEA, the Journal provides a platform for STEM teachers to document and share their classroom experiences and pedagogical innovations. It highlights successes, challenges, and lessons learned, creating a vibrant space for professional growth. Each article represents a meaningful step toward teaching excellence and celebrates the dedication of our teachers.

The Journal fosters cross-disciplinary dialogue, bridging gaps between STEM fields and inspiring new ways of thinking. Each issue features practical case studies, emerging ideas, and reflections that speak to the realities of classrooms and teacher development. Our goal is to provide readers with relevant and actionable insights that enhance practice.

To enrich perspectives and strengthen our professional community, the PJTSE showcases contributions from diverse teachers and education practitioners. Together, their voices present a holistic view of STEM education and its role in addressing contemporary classroom challenges. As we advance, let us continue to embrace discovery, collaboration, and innovation.
We invite readers to share feedback and contribute articles to make the Journal a dynamic space where shared knowledge transforms practice. Plans are underway to transition PJTSE to an Online Journal System (OJS) platform, with ISSN registration in progress. This fith Issue of the PJTSE is published on CEMASTEA's Website and e-Portal.

On behalf of CEMASTEA, I wish you inspiring reading of Volume 5, Issue 1. We welcome continued contributions from educators, trainers, and practitioners to sustain this collective journey of professional excellence.

Mrs. Gladys Masai

CEO, CEMASTEA

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From Barren Land to Living Laboratory: Transforming STEM Education through School-Based Innovation.

By Enock Nthiwa Kaunda

Abstract In resource-constrained schools in Kenya's arid regions, limited access to laboratory equipment and teaching aids often results in passive, abstract STEM instruction that fails to build practical competencies. As a result, learners are denied opportunities for meaningful hands-on experiences, thereby undermining the effective implementation of the Competency-Based Education (CBE) policy. To address this challenge, a 0.25-acre barren school plot at Mapunga High School was transformed into a cost-effective Agro-STEM living laboratory. The project employed a participatory action research approach involving 35 volunteer learners drawn from Grade 10, Form 3, and Form 4. The learners participated in clearing the land, applying mathematics and physics principles to design the layout, and engaging in hands-on interdisciplinary learning using locally available materials. Data were collected through pre- and post-project questionnaires, teacher observations, and photographic documentation over a two-month period. The intervention significantly enhanced learners' conceptual understanding of STEM concepts, with improvements recorded in Biology (48%), Chemistry (45%), Physics (39%), and Mathematics (41%). The project also noticeably increased learner engagement in STEM subjects, with teachers reporting that abstract concepts were grasped more quickly when linked to real-world activities. The significance of this project lies in its scalable, replicable, and low-cost model for improving STEM education in under-resourced schools through the effective use of locally available resources and learner-centred approaches. I recommend that schools facing similar resource limitations establish living laboratories using available land, simple materials, and a curriculum integrated with local contexts. Ultimately, the Mapunga Agro-STEM Project demonstrates that innovative STEM education does not require expensive resources; rather, it requires the creative use of what is already available: land, learners, and a willingness to transform the school compound into a classroom.

Keywords: agro-STEM, experiential learning, learner-centred learning, STEM education, educational innovation, resource-constrained schools

Introduction: Reimagining STEM Education in Resource-Scarce Contexts.

Across the globe, the call for competency-based STEM education has grown louder, yet implementation in low-resource settings remains a persistent challenge. As a science educator with over a decade of experience in Kenyan secondary schools, I have witnessed firsthand how the global push for competency-based STEM education often encounters practical barriers in under-resourced contexts. International bodies such as UNESCO and the African Union have repeatedly emphasised the need for hands-on, context-relevant science teaching to prepare learners for the demands of the 21st century. Yet, translating these global aspirations into classroom reality remains a challenge for many schools across Africa.

In Africa, innovative approaches such as the Knowledge Co-Creation Programme (KCCP) have emphasised hands-on, learner-centred pedagogy (Directorate of National Science Centre, 2025; SMASE-Africa, 2025). These approaches align with the growing recognition that low-cost, context-based interventions can significantly improve STEM learning outcomes in under-resourced schools (Ogunniyi & Rollnick, 2023; Assefa & Melesse, 2024). However, many schools still lack laboratories, consumables, and up-to-date textbooks, forcing teachers to rely on rote learning and abstract explanations.

In Kenya, the government has made significant strides through the Competency-Based Education (CBE), which prioritises practical skills and learner-centred pedagogy. However, a persistent gap exists between policy and implementation, particularly in rural and arid regions where schools often lack laboratories, consumables, and up-to-date teaching materials (Kenya Institute of Curriculum Development, 2023; UNESCO, 2022). The situation is compounded by systemic inequities in resource distribution, leaving many schools to rely on rote learning and textbook-driven instruction.

Tana River County is characterized by its harsh, semi-arid climate and limited access to conventional educational resources. At Mapunga High School, science laboratories are modestly equipped, and textbooks are shared among many learners. Rather than viewing these limitations as insurmountable obstacles, we recognized them as an opportunity to reimagine how STEM education could be delivered. The question became: *How could we create rich, engaging learning experiences without waiting for expensive resources that might never arrive?*

The answer emerged from a combination of local opportunities and professional learning. Following my participation in the 2025 Knowledge Co-Creation Programme (KCCP), organized by the Directorate of National Science Centre (DNSC), Zambia, in collaboration with JICA, I was exposed to innovative hands-on, competency-based STEM teaching approaches (Directorate of National Science Centre, 2025; SMASE-Africa, 2025). This experience inspired a clear vision: to establish a school-based Agricultural Club that would serve as a comprehensive, low-cost Agro-STEM learning laboratory. The goal was to move STEM learning from the abstract

pages of limited textbooks to the tangible and accessible environment of the school compound, demonstrating that effective science education need not depend on expensive resources.

Objectives

1. To establish a cost-effective, school-based Agro-STEM learning laboratory using available land and local materials.
2. To enhance learner engagement and conceptual understanding in STEM subjects through hands-on, interdisciplinary activities.
3. To document the process and outcomes as a replicable model for other resource-constrained schools.

Methodology

Project Design and Approach

This study employed a Participatory Action Research (PAR) design, which was appropriate for addressing the focus of this article because it actively involved learners as co-creators of their learning environment rather than passive recipients of instruction. The PAR approach allowed for iterative reflection and adaptation throughout the project, enabling me to document and refine the process in real-time. This design is particularly suitable for educational innovations in resource-constrained settings, as it emphasises practical problem-solving and local ownership.

Project Genesis: Building a Classroom from Barren Ground

The project began with a formal proposal and a decisive meeting with the school's principal. Recognising the academic value of creating a practical learning space, the principal allocated a dedicated plot of land measuring 0.25 acres within the school compound for the initiative. This administrative endorsement was crucial, providing the legitimacy and space needed to begin constructing an outdoor laboratory.

The first phase engaged the entire school community as builders of their own learning environment. Learners, equipped with basic hand tools (hoes, jembes, rakes, and watering cans), led the clearing of the land. The project drew its core members from 35 volunteer learners across three learning levels: Grade 10 (n=10), Form 3 (n=12), and Form 4 (n=13). Table 1 below shows the distribution by grade and gender.

Table 1

Distribution of Club Members by Grade and Gender

Grade/Form	Female	Male	Total
Grade 10	4	6	10
Form 3	7	5	12
Form 4	6	7	13
Total	**17**	**18**	**35**

Beyond the core club, the project reached over 100 learners through integrated classroom lessons. During designated working days (every Tuesday and Thursday from 4:00 PM to 5:30 PM), additional learners joined activities, gaining hands-on experience in STEM concepts. The garden served as a living laboratory where learners from other classes visited for practical lessons in biology, chemistry, physics, and mathematics.

Data Collection Methods and Tools

To gather and analyse information, we employed a mixed-methods approach using three data collection tools:

1. Pre- and post-project questionnaires: A simple questionnaire was administered to 50 learners (a representative sample of those who would regularly use the garden for learning) before the project commenced and again after two months of hands-on lessons in the living laboratory. The questionnaire assessed learners' self-reported confidence in understanding key STEM concepts and their real-world applications across four subject areas: Biology (plant physiology, growth cycles), Chemistry (soil composition, composting), Physics (pressure, gravity in irrigation), and Mathematics (area, yield calculations). Questions were framed using a Likert-scale format with response options ranging from "*not confident*" to "*very confident.*" The percentage of learners reporting confidence was calculated for both pre- and post-intervention phases.

2. Teacher observations: Four STEM subject teachers (Biology, Chemistry, Physics, and Mathematics) maintained structured observation logs throughout the two-month period. Teachers recorded learner participation rates, questions asked during garden sessions, and anecdotal evidence of conceptual understanding. These observations were discussed during weekly teacher reflection meetings to ensure consistency in documentation.

3. Photographic documentation: The project was visually documented through photographs taken at key stages: land clearing, layout design, planting, and ongoing maintenance activities. This provided visual evidence of the transformation process and served as a supplementary data source for triangulation.

Implementation procedures

I applied STEM principles from the very first day, demonstrating that learning begins with action:

- **Mathematics:** Learners calculated the area and perimeter of the plot (0.25 acres = 10,890 square feet), determined spacing between raised beds, and calculated seed quantities based on recommended planting densities.
- **Chemistry & Agriculture:** Learners discussed soil composition, water retention properties, and the science behind organic manure preparation. They collected soil samples from different sections of the plot and tested pH using locally available indicators (red cabbage extract and litmus paper made from local flowers).
- **Physics:** Learners designed the layout for optimal sun exposure and wind protection, constructed a simple drip irrigation system from recycled plastic bottles (2-litre bottles with pinhole punctures), and observed principles of pressure and gravity in water distribution.
- **Biology:** Learners studied plant physiology through germination and growth cycles of locally available, drought-resistant crops including coriander, pumpkins, *Amaranthus*, and kales. They monitored root development, photosynthesis rates (observing leaf colour and growth patterns), and the impact of organic compost produced from school waste.

All materials except basic hand tools were locally sourced: seeds were obtained from local farmers and the school kitchen, compost materials came from school food waste and dry leaves, and irrigation materials were collected from recycling efforts. This kept project costs near zero, making the model immediately replicable.

I documented the process through photographs, teacher observations, and informal learner feedback. The goal was to create a replicable model that other schools with limited resources could adopt.

Data Analysis

Quantitative data from questionnaires were analysed using descriptive statistics (percentages and frequency counts) to determine pre- and post-project changes in learner confidence levels across subject areas. Qualitative data from teacher observation logs and informal learner feedback were analysed thematically to identify recurring patterns related to engagement, conceptual understanding, and interdisciplinary connections.

Ethical considerations

Participation in the project was voluntary, with learners joining the Agricultural Club by choice. Informed consent was obtained from the school administration and parents/guardians through the

school's regular communication channels. Learner identities have been anonymised in this report, with participants referred to by numbers only (e.g., Learner 5, Learner 23).

Findings

Objective 1: Establishment of the living laboratory

The first objective sought to establish a cost-effective, school-based Agro-STEM learning laboratory using available land and local materials. Within two months, the previously barren plot was transformed into a productive garden with:

- **Raised beds:** Ten raised beds measuring 1m × 2m each, constructed using locally available timber and filled with enriched soil mixed with organic compost.
- **Compost area:** A designated 3m × 3m composting site where learners converted school food waste and dry leaves into nutrient-rich organic manure.
- **Drip irrigation system:** A functioning irrigation system made from 50 recycled plastic bottles (2-litre capacity each), connected using simple tubing and gravity-fed from a 200-litre water tank.
- **Nursery beds:** Two nursery beds for seedling propagation, protected from direct sunlight using locally woven grass mats.

All materials except basic hand tools were locally sourced, keeping costs near zero. The total expenditure for the project was KES 2,500 (approximately USD 19), spent on seeds and basic hand tools. This demonstrates that the establishment of a functional living laboratory is feasible even with minimal financial resources.

Club members proudly planted their first crops as shown in Pictures 1, 2 and 3 below, transforming barren land into a living laboratory where every plant becomes a learning opportunity and every learner becomes both learner and teacher.



Picture 1: *Amaranthus.*



Picture 2: Pumpkin seedlings



Picture 3: Pumpkin seedling

Objective 2: Learner Engagement and Conceptual Understanding

The second objective aimed to enhance learner engagement and conceptual understanding in STEM subjects through hands-on, interdisciplinary activities. To assess the project's impact, teachers administered a simple pre-project questionnaire to 50 learners (a representative sample of those who would regularly use the garden for learning). After two months of hands-on lessons in the living laboratory, the same learners completed a post-project questionnaire. Table 2 below shows the percentage of learners who reported feeling confident in understanding key STEM concepts and their real-world applications.

Table 2

Percentage of Learners Reporting Improved Conceptual Understanding

Subject Area	Pre-Project (%)	Post-Project (%)	Change (%)
Biology (plant physiology, growth cycles).	38	86	+48
Chemistry (soil composition, composting).	29	74	+45
Physics (pressure, gravity in irrigation).	32	71	+39
Mathematics (area, yield calculations).	44	85	+41

The largest gains were observed in biology and chemistry, subjects most directly connected to daily garden activities. Learner 5 (Grade 10) reported that *"seeing the plants grow made photosynthesis real"*. Learner 23 (Form 4) noted that *"calculating the area of the beds helped me understand why we learn formulas"*

Teachers' observation logs provided additional evidence of increased engagement.

The biology teacher recorded: *"Before the project, learners struggled to differentiate between monocot and dicot roots. After our garden session where we uprooted Amaranthus (dicot) and compared it with maize (monocot) from the school farm, all learners could correctly identify root systems."*

The mathematics teacher noted: *"Learners who previously avoided mathematics problems eagerly calculated seed spacing and harvest estimates. The garden transformed abstract numbers into tangible outcomes."*

Objective 3: The Agro-STEM Model as a Replicable, Cost-Effective, Interdisciplinary Curriculum

The third objective sought to document the process and outcomes as a replicable model for other resource-constrained schools. The core innovation of the project is its demonstration that rigorous STEM education can be delivered with minimal financial resources when local materials and contexts are leveraged. Every agricultural activity becomes a vehicle for delivering standard curriculum content, eliminating the need for expensive laboratory equipment or teaching aids. The garden is not an extra-curricular hobby; it is a primary classroom where learning is rooted in direct experience *(Mutegi et al., 2025)*.

- **Biology in Action:** Learners studied plant physiology through the germination and growth cycles of locally available, drought-resistant crops like coriander, pumpkins, *Amaranthus*, and kales. They monitored root development, photosynthesis, and the impact of organic compost they produced themselves from school waste. The garden served as a living biology laboratory that costs nothing to maintain.
- **Chemistry at Work:** Lessons on soil chemistry came alive as learners tested soil pH using locally available indicators (red cabbage extract and local flower pigments), monitored nutrient levels through observation of plant health indicators (leaf colour, growth rate), and understood the science behind the organic manure they prepared. The process of creating compost became a practical lesson in decomposition and biochemistry, replacing expensive chemical experiments with real-world applications.
- **Physics Principles Applied:** Designing and building a simple drip irrigation system from recycled plastic bottles taught principles of pressure, gravity, and water conservation—critical skills in arid regions. Learners constructed their own measuring devices and observed how light and heat affected plant placement in nursery beds.
- **Mathematics for Real-World Problem Solving:** Learners constantly engaged in practical calculations: tracking growth data in homemade notebooks, calculating harvest yields, measuring rainfall with simple gauges, and managing the project's resource allocation. Mathematics became immediately relevant and applicable.

Teachers noted that learners who previously struggled with abstract topics became more willing to participate in discussions after hands-on garden activities. The garden also encouraged cross-form collaboration, with older learners mentoring younger ones during planting and data collection exercises.

Dual Impact: Maximising Learning from Minimal Resources

The project demonstrates that resource scarcity need not limit educational quality:

1. **Creating rich learning from simple materials:** Learner engagement in Biology, Chemistry, Physics and Mathematics has noticeably increased, despite or perhaps because of the absence of sophisticated equipment. Teachers report that abstract concepts are now grasped more quickly because learners have real-world reference points constructed from everyday materials. The project fosters critical 21st-century skills: problem-solving, teamwork, data literacy, and innovative thinking; all developed without expensive technology.

2. **Demonstrating a replicable model for resource-constrained schools:** The project proves that schools need not wait for government-provided resources to deliver quality STEM education. By viewing the school compound itself as an educational resource, by engaging learners as active participants in building their learning environment, and by connecting the curriculum to local context, even the most poorly resourced school can create rich learning opportunities.

Discussion and Reflection

This project confirms that educational resources are not limited to what is purchased; they include the land, the community, and the creativity of teachers and learners. We moved from a deficit mindset; *"we lack resources"* to an asset-based approach: *"what can we do with what we have?"* This shift reflects principles of asset-based community development, which emphasises leveraging existing local resources rather than focusing on deficiencies (Kretzmann & McKnight, 1993; Mathie & Cunningham, 2003).

The learners' role as co-designers was crucial. They not only built the garden but also suggested which crops to plant based on local knowledge (prioritising drought-resistant varieties like *Amaranthus* and pumpkins) and which STEM concepts to explore first (starting with soil testing and germination). This ownership increased their motivation and deepened learning, as evidenced by the high participation rates and the qualitative comments captured in teacher observation logs.

A key reflection is that such projects require initial administrative support and a willingness to step outside traditional classroom boundaries. The principal's allocation of land and endorsement of the project were critical enabling factors. Additionally, teacher training through programmes like KCCP provides the pedagogical foundation needed to facilitate experiential, interdisciplinary learning. However, once established, the living laboratory becomes self-sustaining and continuously yields new learning opportunities with each planting cycle.

The project's interdisciplinary nature is particularly noteworthy. Rather than teaching STEM subjects in isolation, the Agro-STEM model demonstrates how Biology, Chemistry, Physics, and Mathematics naturally interconnect in real-world agricultural contexts. This aligns with global calls for integrated STEM education and addresses a persistent challenge in many African schools where subjects are taught separately and abstractly *(Ogunniyi & Rollnick, 2023)*.

Practical Significance and Applicability to Classroom Practice

The findings of this project are applicable to classroom practice for other teachers in several ways:

Direct Replicability: The model requires only a small plot of land (0.25 acres or less), basic hand tools, and locally available seeds. Schools with limited financial resources can adopt this approach immediately without waiting for government funding. The step-by-step process documented in this article provides a clear implementation guide for other teachers.

Curriculum Integration: Teachers across all STEM subjects can integrate the living laboratory into their lesson plans. For example, Biology teachers can use the garden for plant physiology lessons, Chemistry teachers for soil and composting experiments, Physics teachers for irrigation and energy concepts, and Mathematics teachers for measurement and data analysis. The project provides concrete, real-world examples that make abstract concepts tangible.

Cross-Disciplinary Expansion: While this project focused on STEM subjects, the living laboratory model has potential applications to other disciplines. Business Studies teachers, for instance, could use the garden to teach:

- **Financial literacy:** Budgeting for seeds, tools, and irrigation materials.
- **Bookkeeping:** Tracking expenses, harvest yields, and potential sales of surplus produce.
- **Entrepreneurial skills:** Developing a business plan for selling produce, calculating profit margins, and understanding supply and demand.
- **Marketing:** Designing packaging and promotional materials for garden produce.

Future iterations of this project should include Business Studies teachers in the planning and implementation phases, documenting how the garden can serve as a cross-curricular resource. This would further enhance the model's practical significance and demonstrate its relevance across the entire school curriculum.

Learner-Centred Pedagogy: The project exemplifies learner-centred, experiential learning that aligns with Kenya's Competency-Based Education policy. Teachers can adopt this approach to move from teacher-centred, lecture-based instruction to active, participatory learning that builds practical competencies.

Conclusion

The Mapunga Agro-STEM Project demonstrates that learner-centred STEM education can be successfully implemented in resource-constrained environments without waiting for expensive materials or facilities. The project achieved its three objectives:

1. **Establishment of the living laboratory:** A 0.25-acre barren plot was successfully transformed into a productive Agro-STEM learning laboratory within two months, using locally available materials at a cost of less than USD 20. The laboratory includes raised beds, a composting area, a drip irrigation system from recycled bottles, and nursery beds; all built by learners.

2. **Enhanced learner engagement and conceptual understanding:** Pre- and post-project assessments revealed significant improvements in learners' self-reported confidence across all four STEM subjects: Biology (+48%), Chemistry (+45%), Physics (+39%), and Mathematics (+41%). Teacher observations confirmed increased participation, better retention of concepts, and improved interdisciplinary thinking among learners.

3. **Documentation of a replicable model:** The project has been thoroughly documented, providing a clear, step-by-step guide that other resource-constrained schools can follow. The model is scalable, requiring only available land, simple materials, and a curriculum integrated with local context. The project has gained recognition through its publication on the SMASE-Africa platform, further enhancing its potential for replication.

By viewing local context as an asset rather than a limitation, the project has created rich, engaging learning experiences from simple resources. This model can be replicated in other schools, particularly those in resource-limited settings, demonstrating that educational innovation often comes not from abundant resources but from creative responses to scarcity. When learners become co-creators of their learning environment, the entire school compound becomes a classroom, and barren ground transforms into fertile ground for the mind.

For schools seeking to replicate this model, I offer the following recommendations:

i. Secure administrative support and a dedicated plot of land;
ii. Engage learners as co-designers from the outset;
iii. Integrate the living laboratory into the regular curriculum across multiple subjects;
iv. Document the process for continuous improvement and knowledge sharing;
v. Consider expanding the model to include non-STEM subjects such as Business Studies for a truly interdisciplinary approach.

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From learners to architects: Empowering learners as Co-Designers of Chemistry Pedagogy

Alice Machocho Mwang'ombe

Abstract This study investigated pedagogical gaps contributing to persistent underperformance in Chemistry at Juhudi Girls' High School. Using an action research design, the study sought to capture the student voice regarding attitudes toward Chemistry, study habits, and the academic challenges influencing achievement. A pre-intervention diagnostic survey was administered to a random sample of 303 learners drawn from a population of 1,179. From each of the school's 20 streams, 15 learners were randomly selected to participate in the survey.The survey aimed to identify learners' perceptions of factors contributing to low performance and to gather their proposed strategies for improvement. Findings revealed widespread dissatisfaction with Chemistry results, with 92.1% of respondents expressing concern about their grades. Learners largely attributed their underperformance to limited conceptual understanding of key topics and insufficient opportunities for regular retrieval and remedial practice.Based on learners' feedback, the study recommends adapting the structured support model successfully used in the school's Mathematics department. This model includes frequent topical assessments and dedicated subject support hours to reinforce understanding. Such practices help normalize testing, reduce examination anxiety, and build cumulative academic confidence. The findings underscore the value of incorporating learners' voice when designing pedagogical interventions aimed at improving learning outcomes in challenging subjects such as Chemistry. Crucially, the implications of this study extend far beyond to offer a replicable model for all cadres of schools navigating similar STEM performance gaps. Furthermore, the findings serve as a catalyst for regional teacher professional development, demonstrating how structured student-teacher collaborative feedback loops can enhance instructional capacity. Ultimately, this study provides actionable insights for curriculum implementers under the Competency-Based Education (CBE) framework, advocating for a systemic shift toward participatory pedagogy to seal the leaking pipeline for learners particularly girls in the sciences.

Keywords:Action research; student voice; chemistry education; structured pedagogy

Introduction

In nearly all secondary schools, there exists a puzzling academic trend where learners excel in science than they do mathematics. Specifically, for girls' schools, the trend is a conspicuous factor that majorly contributes to female under-representation and the leaking pipeline of women in STEM careers (Smith and Evans 2024). Most learners are locked out in pursuing lucrative STEM courses and careers when they underperform in math and science subjects. However, some secondary schools face a reversal of this academic trend where science is underperformed when compared to mathematics.

Such disparities often lead to institutional pressure on department heads to implement corrective measures. Understanding why this reversal of the typical academic trend occurs is crucial for improving STEM outcomes in schools. Heads of departments in schools can apply action research to identify gaps in their departments as well as interventions to find solutions from the learners themselves. The purpose of this article is to offer practical insights into how action research can empower learners as co-designers in the improvement of their learning environment (Makela, Helfenstein et al. 2018). By bridging the gap between learners' attitudes and academic results, educators can better support the academic journey through evidence-based pedagogical adjustments as alluded to in Mertler (2024).

Literature Review

Empowering Learners as Co-Designers of Pedagogy

Globally, the transition toward empowering learners is defined by the shift from passive instruction to active engagement. This paradigm shift has enabled teachers and learners to share responsibility for navigating the learning path. Dang (2025) refers to this type of engagement as learner agency which is broadly defined as learners' active involvement in their learning and decision making in their learning experiences. Consequently, empowering learners to be co-designers of pedagogy enables them to gain control over their learning environment and achieve goals despite challenges.

The Sub-Saharan African literature focuses on hybrid pedagogy as a way in which learner-centered inquiry is embraced to ease teaching and learning. A critical element of this learner empowerment is the gender-responsive pedagogy which FAWE (2023) argues is most effective when girls are active co-designers of their learning environments to prevent the leaky pipeline in STEM. FAWE's claim is also supported by Mwang'ombe and Mwingi (2023) who assert that empowering learners to actively participate in their learning can aid in enabling especially girls to defy the gendered norms in science.

Kenya's Competency-Based Curriculum (CBC) framework identifies learner engagement and empowerment as a core pillar, allowing learners to choose specialized pathways that align with their career aspirations (KICD, 2023). This shift is operationalized through Inquiry-Based learning (IBL). IBL transforms learners into investigators who design their own experimental procedures rather than merely following instructions from their teachers, a practice which was mirrored in the traditional 8-4-4 system (CEMASTEA, 2022). However, Sifuna and Obonyo (2019) highlight that traditional teacher-centered teaching and learning remains a significant barrier to the full realization of student-inclusive co-design in Kenyan classrooms.

Retrieval Practice and Formative Assessment in STEM Education

Contemporary cognitive research and scientific pedagogy advocates for retrieval practice and formative assessment as crucial strategies for enhancing conceptual retention and problem-solving effectiveness in STEM fields. Retrieval practice is the act of deliberately bringing learned information to mind and it is a highly effective mechanism for mitigating cognitive load (Abbott 2025). In conceptually demanding subjects like senior school chemistry, abstract problem-solving often strains a learner's working memory. Therefore, routine retrieval interventions such as quizzes or structural concept mapping strengthen learners concept retention and frees up cognitive capacity, allowing them to navigate through abstract concepts (Carpenter, Pan et al. 2022). When combined with interactive formative assessment cycles, these diagnostic retrieval interventions transform from top-down evaluations into collaborative tools for 'assessment for learning' which aligns with Competency Based Education (CBE) (Lafferty and Barnes 2024). Actively involving the student voice in the design of these formative assessments promotes learner science self- efficacy and creates a more equitable learning environment.

Despite the acknowledged success of these student-focused approaches worldwide, a clear gap exists in implementing these strategies in senior school STEM classes moving towards modern competency-based education (CBE) models (Nayak and Nayak 2026). While national educational reforms promote interactive, learner centered approaches, teaching often reverts to traditional, teacher-centered learning due to teacher rigidity and lack of learner involvement as co-designers of pedagogy. Educators are often challenged to dynamically adapt their pedagogy based on real-time learner feedback. By systematically leveraging the student voice to reconstruct instructional models for chemistry, this study provides a scalable and replicable framework to improve performance and secure the STEM pipeline in senior schools.

The Catalyst: A Chilly Monday Wake-Up Call

Did you know that the best pedagogical solutions are sitting right in front of us in our classrooms, waiting to be asked? It was a chilly Monday afternoon in August 2025, and the atmosphere at Juhudi Girls' High School was heavy with the anticipation of the new term. The staff meeting, called by the Chief Principal, aimed to plan for the term as well as analyzing the

End of Term 2 examination results. In his familiar routine, the Dean of Studies took us through the examination analysis. When he got to chemistry, a glaring disparity emerged. Have you ever wondered why and how girls can do well in mathematics but do poorly in chemistry? This thought would not leave me, and I even said it aloud. Moreover, this phenomenon according to me is so contrary to most literature describing girls and STEM (Gichaga 2023, Musango and Marwa 2023, Ochwada 2024, Smith and Evans 2024). While our learners excelled in Mathematics, their performance in Chemistry was not appealing at all. The chemistry mean scores in all classes were low and for a teacher with 11 years' teaching experience in all cadres of schools, this felt like a mysterious reversal of the typical academic trend especially for girls.

As the Head of Department, the hammer of accountability landed squarely on me before it trickled down to other members. The wrath of failure fell on me! It was agreed that immediate, evidence-based action was required to bridge this performance gap. Driven by a need to understand the "why" behind the numbers, I burnt the midnight oil designing a comprehensive google form capturing both qualitative and quantitative prompts that would yield the required data. The goal was simple yet ambitious: to conduct a diagnostic survey that captured the learners' voice. We sought to identify the pedagogical gaps that allowed Chemistry diminished performance. The Chief Principal supported the idea and provided airtime for two teachers per stream to facilitate the digital survey.

Objectives

This study was guided by the following general objectives:

i) To use a diagnostic survey to gather learners' perspectives on attitudes toward chemistry at Juhudi school.

ii) To capture and amplify the learners' voice on the current study habits, conceptual challenges, and lived realities in the chemistry classroom at Juhudi school.

iii) To determine pedagogical gaps contributing to low learners' performance trends in Chemistry at Juhudi school.

Methodology

The study is embedded within a broader action research cycle in which the planned intervention would subsequently be implemented, observed, and reflected upon. However, this paper focuses on the reconnaissance and planning phase, whereby a diagnostic survey with both qualitative and quantitative questions was administered. Out of a total population of 1,179 learners, 303 learners were randomly sampled with a representation of approximately 15 per stream across forms two, three and four. Moreover, the random sampling technique ensured a representative sample and

minimised bias since each learner had an equal chance of being selected according to (Makwana, Engineer et al. 2023). This diverse group provided a comprehensive view of the school's chemistry academic landscape. The diagnostic survey instrument underwent content validity vetting and was pilot tested with a group of 10 participants for reliability before full administration. This action research approach was designed to move beyond teacher assumptions and look directly at the learners lived realities which clearly agree with (Mertler 2024). Quantitative performance metrics were evaluated using descriptive analysis by utilizing percentage distributions generated via automated tables and pie charts (Ulum, Basuki et al. 2023). Qualitative insights from the student survey were processed using thematic analysis to identify recurring patterns. Ethical considerations including anonymity of the school and participants in accordance with Haneef and Agrawal (2024) were made and adhered to.

Findings

Learners Demographic Information

The pie chart in Figure 1 represents the proportion of learners from each class who took part in the survey.

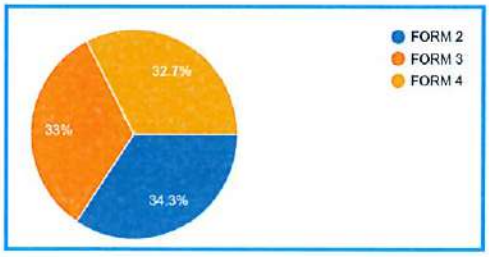


Figure 1: Juhudi Girls learners' demographic information

Figure 1 shows that 34.3% of form twos, 33% of form threes and 32.7% of form fours participated in the survey. The respondents were aged between 15-17 years and were all girls.

Juhudi Learners' Perspectives on Attitudes Toward Chemistry

Figure 2 illustrates the general attitude towards chemistry among learners, categorized into three distinct levels of engagement: 'I love it,' 'I am neutral,' and 'I dislike it.

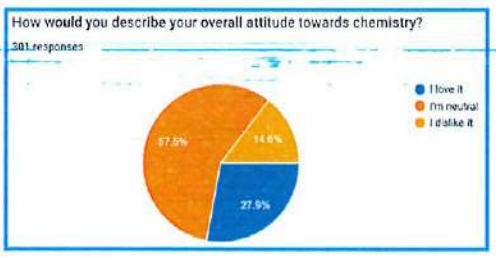


Figure 2: Juhudi Girls learners' attitude towards chemistry

On learners' attitude in chemistry, the findings revealed a disconnect between learners' academic goals and their reality. While a significant portion of around 173 (57.5%) learners maintained a neutral attitude, 84 (27.9%) loved the subject and 44 (14.6%) confessed to having disliked the subject. This kind of attitude is further illustrated in figure 3 which shows Juhudi learners chemistry scores in their internal examinations.

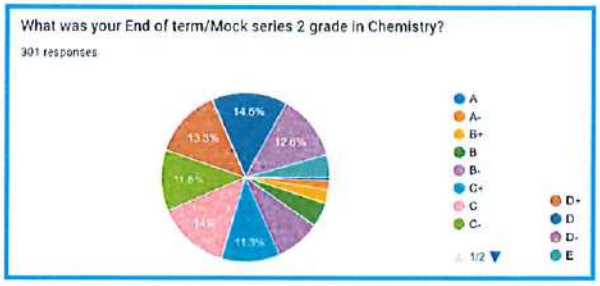


Figure 3: Juhudi Girls End-of-Term/Mock Series 2 grades

Most of the learners' performance in chemistry is within the C to D range which could be interpreted as average and poor respectively. This suggests a heavy distribution where many learners have a foundational understanding of chemistry but may be struggling to reach higher quality grades. However, even amidst the low performance, figure 4 below illustrates how learners highly rated their self-perceived confidence levels in chemistry performance.

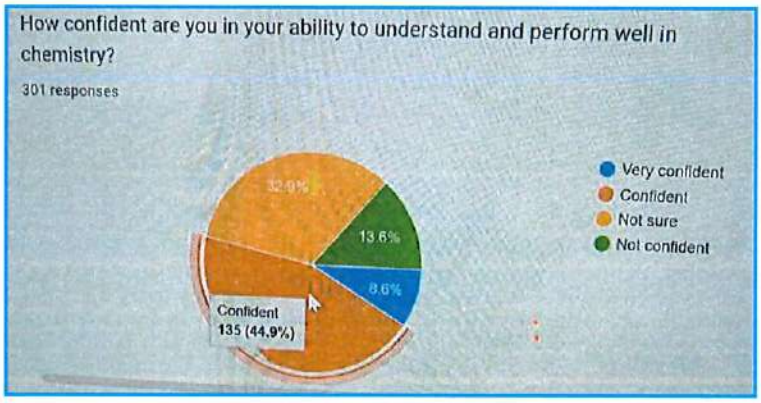


Figure 4: Self-Perceived Confidence Levels in Chemistry Performance Among Learners

The findings revealed that despite a backdrop of low chemistry performance, a significant majority 135 (44.9%) and 8.6% of learners maintain a positive outlook, with over half expressing some level of confidence in their ability to master and succeed in chemistry.

Learners' Voice on Study Habits and Conceptual Challenges

In this study, learners were asked about the specific difficulties of the subject. Learners' perceptions of difficulty in chemistry theory vs. practical components are highlighted in figure 5 below.

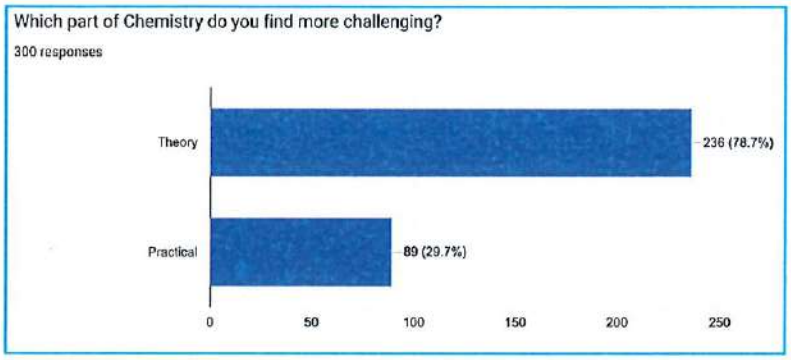


Figure 5: Learners' Perceptions of Difficulty in Chemistry Theory vs. Practical Components

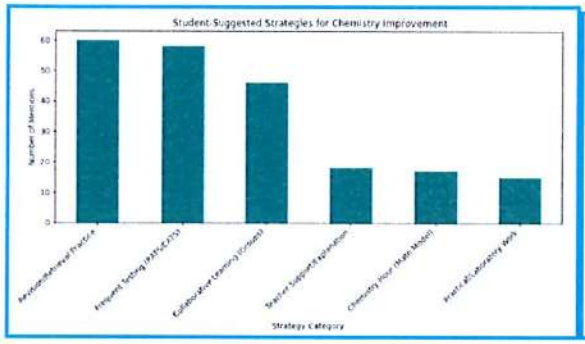
It is evident in figure 5 above that 236 (78.7%) respondents identified the theoretical aspects of chemistry as more challenging than practical work. Moreover, the learners voice also highlighted that the primary obstacle was not a dislike of the subject, but a slight lack of understanding in theoretical concepts and their application to exam questions as learner 77 puts it; '*Chemistry is difficult to understand. Like I really love and admire how my teacher teaches. She repeats and repeats and even uses revision books after everything we do. But I don't understand some things R77.*' Some other learners cited difficulties with calculations, memorization, and a lack of adequate study materials as major barriers to chemistry performance.

Learners Voice on Pedagogical Gaps in Chemistry at Juhudi School

The most significant insight from the study was the learners' explicit request to replicate the school's successful mathematics department's model. This hitting revelation was contrary to the assumption that learners wanted a lighter workload. The girls suggested that they wanted more consistency, and it was evident that there was a critical deficit in frequent topical testing within the Chemistry department as compared to Mathematics. They were not failing because the content was too hard; they were failing because they were not practicing retrieval as often as it was done in mathematics department; '*Yes. I have come to like mathematics because of the effort the teachers put. Chemistry can also do the same R15.*' The Student Voice was clear as they explicitly requested that the Chemistry department copy the mathematics model of constant

retrieval practice. They cited that the frequent testing in Math reduced their exam anxiety and built a sense of cumulative confidence that was missing in chemistry as shown in the verbatim responses in the figure 6 above.

According to the girls in Juhudi, the constant retrieval practice was the cornerstone of success in mathematics. The proposed strategy involves implementing regular topical testing (RATS), and Continuous Assessment Tests (CATS) immediately after each topic; *"Give us more exams and revision like in maths R3."* Moreover, more student suggested strategies for chemistry improvement are shown in figure 7 & 8 below.



Strategy Category	Mentions	Student-Suggested Action (The "Math Blueprint")
Frequent Retrieval Practice	58	Implementing RATS (Random Assessment Tests) and CATS immediately after topics.
Dedicated Study Time	17	Establishing a dedicated "Chemistry Hour" similar to the existing "Math Hour."
Revision & Mastery	60	Increasing the frequency of practice papers and retrieval exercises.
Collaborative Learning	46	Formalizing peer-teaching and group discussion sessions.

Figure 7&8: Student-suggested strategies for Chemistry improvement

Subsequent data revealed that learners were demanding introduction of the chemistry hour which entailed establishing a dedicated time for focused study and practice, mirroring the successful Math program. Collaborative learning was also part of the model where there was increased peer teaching and teacher-supervised group discussions to solidify conceptual understanding.

Discussion and Reflection

Bridging the Gap: Aligning Instruction with the Learner's Voice

The feedback from the study transformed our departmental strategy and most importantly the realization that learners were capable of being co-designers of their own learning environment. This claim is in line with Mäkelä, Helfenstein et al. (2018) that engaging learners in instruction built a collaborative culture and highlighted their priorities for education. Who would have thought that learners would ask for more tests? The Chemistry team immediately began a pedagogical journey of emulating the mathematics blueprint. This meant moving away from bulky end-of-term assessments toward regular topical quizzes, a strategy that would at least solve the neutrality and dislike of the subject which was conspicuous in the findings. Moreover, the math-science synergy enabled us to align our testing frequency with the successful structures used by the Math department as well as realize the importance of incorporating learners feedback into our departmental planning which agrees with Dang (2025) argument on student agency. The

learners' voice revealed that learners do not necessarily find the content too hard but rather struggle with how it is structured and reinforced by the teachers.

Furthermore, action research as alluded in Mertler (2024) underscored the transformative potential of empowering learners as co-designers of their own learning environment. As teachers we learnt that indeed learners can provide the very blueprints needed for their own success, a fact that most teachers ignore as alluded in (Sifuna and Obonyo 2019). The diagnostic survey identified specific pedagogical gaps in chemistry such as inconsistent testing, examination anxiety, dedicated chemistry hours or formal collaborative learning sessions that had already proven successful in the mathematics department. By adopting the strategies suggested by the learners themselves, the Chemistry department is now moving from a place of "wrath" and underperformance to a proactive, student-centered culture of chemistry excellence. The journey of 'aping' Math to ace Chemistry proves that sometimes, the best pedagogical solutions are sitting right in front of us in our classrooms, waiting to be asked. Ultimately, empowering learners to provide actionable feedback allows for a more supportive and effective learning environment.

Conclusion

The diagnostic survey at Juhudi Girls' High School reveals a notable disconnect between student effort and achievement in Chemistry. Findings suggest that the challenge is neither the level of academic demand nor the attitude towards chemistry, but the structure of learning and assessment. Moreover, the learners voice indicated a preference for greater instructional consistency and more frequent topical testing, practices that may reduce anxiety while strengthening conceptual retention. Through the action research process, the Chemistry department identified retrieval practice and collaborative learning, approaches already used successfully in Mathematics, as promising strategies for improving performance. Furthermore, these insights highlight the importance of structured practice and formative assessment in supporting learners' confidence and mastery in Chemistry. Future cycles of the action research will implement and evaluate these strategies to determine their impact on learners learning outcomes.

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Creating Safe and Supportive Mathematics Classrooms: For Learners Impacted by Alcohol, Drug, and Substance Abuse in Secondary Schools

Denis Kibaki

Abstract Learners in secondary schools, especially day schools, are greatly affected by domestic violence, alcohol, drugs, and substance abuse within their homes and communities. These challenges negatively affect their learning, with the greatest impact being on the understanding of concepts in mathematics. Learning mathematics requires teamwork, communication, collaboration, and critical thinking. These core competencies require emotional stability, the lack of which has contributed to low concentration, emotional instability, absenteeism, and behavioral challenges, leading to reduced performance in mathematics. These observations prompted me to maintain a predictable routine, avoid harsh punishment and use supportive corrections after which I observed learners feel secure and ready to learn. I went further to do emotional check-in by beginning each lesson with a quick 2-minutes simple signals like thumbs up/down. This builds trust and emotional safety. Peer assisted learning in small groups by assigning mixed ability groups to solve real life quadratic problems e.g area of land and with step by step guide increased learners' participation and reduced anxiety. With these interventions, learners' performance in mathematics started improving. This article aims to contribute practical insights for educators working in challenging contexts. By focusing on supportive mathematics teaching practices, the study seeks to improve both academic performance and learner well-being. The findings will be particularly relevant for teachers, school leaders, and policymakers aiming to address the intersection of substance abuse and education.

Keywords: *Safe learning environments, trauma-informed pedagogy, domestic violence, Basic Education Act, Children Act*

Introduction

One way of determining whether learners are understanding a concept is by reviewing the previous lesson before introducing a new one. It was during such a review that a worrying trend was noted, prompting the need to further review the learners' progress work in a Form Three mathematics class. During the review, it was noted that many learners did not complete the homework adequately, despite having demonstrated understanding of the concept during the lesson.

Further inquiry revealed that among those who had completed the assignment, 80% was copied work, and learners had little or no clue how to perform the task independently. An examination of the causes of this trend revealed that a number of learners were facing domestic violence, alcohol misuse, drug use, and substance abuse, which contributed to low concentration, emotional instability, and behavioral challenges that negatively affected their performance in mathematics. By creating a safe learning environment, using trauma-informed pedagogy, and adopting low-pressure assessment strategies, learners became motivated, leading to increased classroom concentration, emotional stability, and positive behavioral change.

A Practical Classroom Experience

The Form Three class had been underperforming from Form Two, with the lowest score registered in mathematics when more new concepts started being introduced. Most of the time, 80% of the learners seemed unbothered by their low performance, something that concerned me as the mathematics subject teacher.

Interventions Made for Improved Performance

In my attempt to address the problem, I adopted an action research design involving 4 groups each comprising 3 learners. The groups were recorded as learners 1 to 4 in the data table below with their mathematics average scores were recorded in the table for midterm 3 form two exam as the baseline.

Table 1

A sample of Learners Progress and Challenges Before Intervention

Group No.	Entry Behavior (X/500)	Homework Uptake (%)	Midterm Score (%)	Observed Challenge
1	321	10	4	Domestic violence
2	210	5	2	Alcoholism
3	333	25	23	Drug use
4	177	15	4	Domestic violence

The intervention made included parental engagements and trauma informed teaching. The data was statistically analyzed and presented as in the table 2 below. These interventions together with strengthened guidance and counselling services where external qualified counsellors were invited for counselling, introduction of low-pressure assessments and Positive behavior support prioritized over punitive measures lead to homework uptake Improvement with notable positive deviation in the first term form 3 mathematics end of term exam as compared to midterm 3 form two by exam result by the same group of students.

Table 2

Learner Progress After Supportive Interventions

Group No.	Homework Uptake (%)	Midterm Score (%)	End-Term Score (%)	Outcome
1	40	4	41	Improved confidence
2	35	2	15	Gradual improvement
3	75	23	37	Improved engagement
4	55	4	25	Positive attitude change

During the study, confidentiality of the learners, their consent and protection were ensured. The identity of the learners was also concealed and only numbers were used to represent the 4 groups

My Reflection

This experience reinforced the importance of understanding learner behavior through a well-being lens. Many learners were not unmotivated but were responding to trauma and instability at home. When emotional safety and support were prioritized, learners showed increased engagement, confidence, and improvement in mathematics.

Conclusion

Poor performance in mathematics can stem from domestic violence, alcohol abuse, and drug and substance misuse, particularly in day secondary schools. I therefore encouraged mathematics teachers and other educators to implement whole-school routines that promote safety and predictability, trauma-responsive instructional practices, integrated guidance and counseling services, positive behavior support, and low-pressure assessments. These approaches reduce anxiety, enhance learner well-being, and improve academic performance

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From a sage on the stage to a guide on the side.

Festus Mugendi Muriuki

Abstract Educational reforms introducing Competency-Based Education (CBE) have significantly redefined classroom practice. It has shifted the teacher's role from the traditional *"sage on the stage"* to a *"guide on the side."* This article presents a critical classroom incident that illuminates the tensions experienced by teachers transitioning from the traditional 8.4.4 curriculum to Competency-Based Education. It focuses on an experienced secondary school Mathematics teacher who, while teaching trigonometry in a Grade 10 class, employed conventional teacher-centered methods characterized by clear explanations and procedural demonstrations in a pin-drop silent class. Although the lesson appeared successful, subsequent assessment revealed widespread misconceptions among the learners. A question from one of the learners during feedback exposed a fundamental conceptual gap, prompting the teacher to reconsider his instructional approach. This incident triggered professional reflection and collegial consultation within the mathematics department. During the meeting, emphasis was placed on the teacher's evolving role as a facilitator of learning rather than a transmitter of knowledge. In response, the teacher redesigned the lesson using learner-centered strategies, including group discussions, guided inquiry, and collaborative problem-solving. This shift enabled learners to actively engage with concepts, confront misconceptions, and construct accurate understanding, leading to improved performance.

Keywords: ***Competency-Based Education, Teacher identity, Learner-centered pedagogy, Curriculum reform, Professional transition, Reflective practice.***

Introduction:

The transition from content-based education to Competency-Based Education presents profound challenges for established professional teachers. Under 8.4.4, success is often measured by content mastery, classroom control, and the teacher being mainly the source of knowledge. Learners are positioned as passive recipients of knowledge. CBE, however, requires learners to be active and collaborative. Learner involvement is emphasized in the research by Walker & Koralesky-2021 showing that it is particularly difficult for learners to write essays without continual discussion, even if it is to reinforce what is already taught. When learners are allowed to actively participate in teaching and learning, misconceptions come out clearly; otherwise they

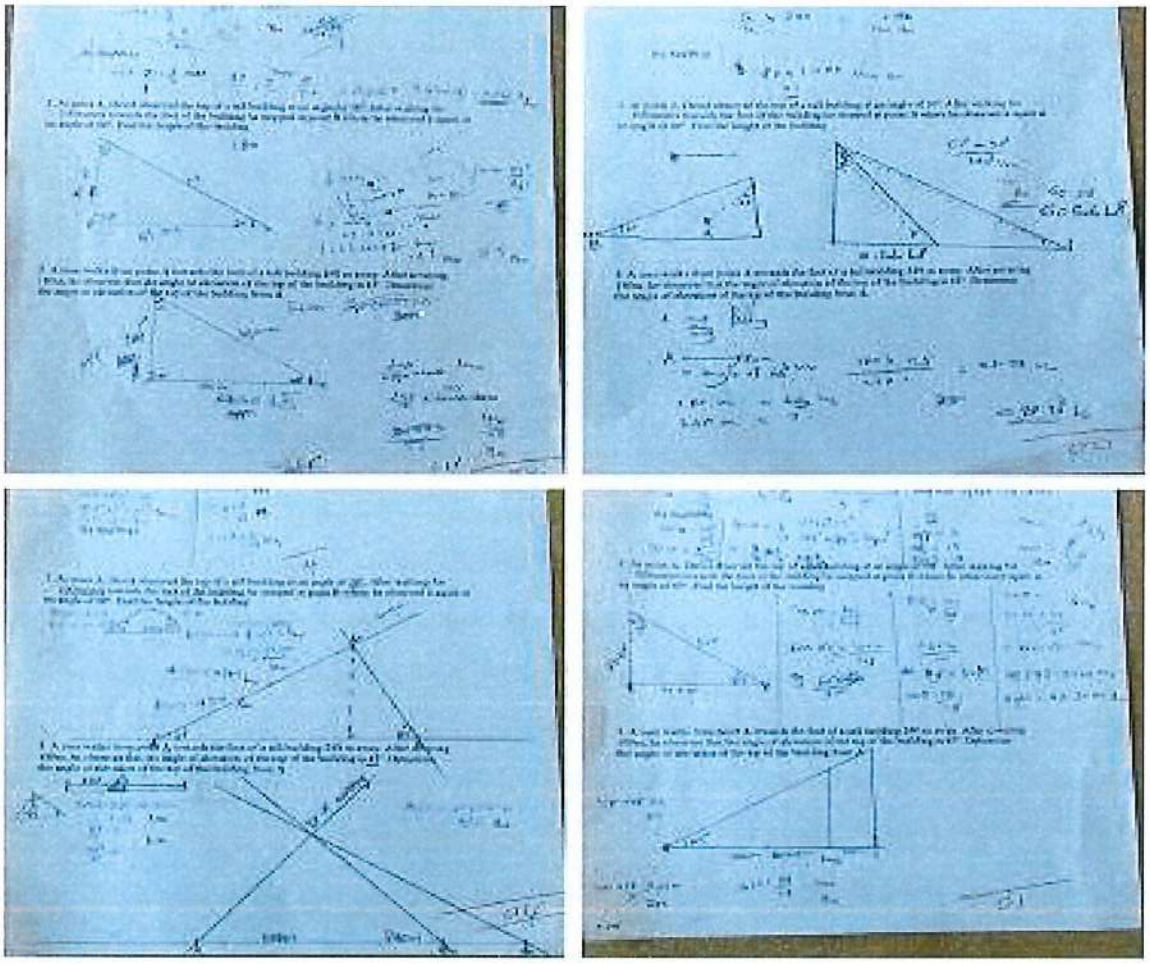
remain hidden in learners' passive engagement and only surface when learners are given assignments and cannot do them correctly. For meaningful learning to take place, the role of the teacher must be clearly defined. Taylor and Francis -2021 emphasizes the importance of examining the role of teachers in developing students' critical thinking and, specifically, enhancing their ability to evaluate information. With the inception of CBE, learners's involvement is key during lesson delivery. This has triggered reflection on long-held assumptions about teaching and learning. This shift demands not only methodological change but also deep professional and personal transformation, as educators renegotiate their roles from authoritative instructors to facilitators of meaningful learning. This calls for action by all stakeholders to continually build capacity as teachers transition to CBE. The teacher as a facilitator should be equipped with some important skills to create and facilitate an active learning environment in the classroom (Gautam &Agarwal, 2023).

A Critical Classroom Incident

Mr. Karumaido (not his real name), an experienced Mathematics teacher at Kiwaru Senior School (not a real name), had taught Mathematics for over two decades under the 8.4.4 curriculum. He was assigned to co-teach core mathematics with Madam Chik in grade 10. Mr Karumaido was assigned trigonometry. Confident in his mastery of content and classroom control, he approached a grade 10 lesson on *Angles of Elevation and Depression* as an application of trigonometry using methods that had consistently produced good examination results in the past. At the beginning of the lesson, Mr. Karumaido clearly introduced the concept by defining angles of elevation and depression and illustrating them using neatly drawn diagrams on the chalkboard. He systematically explained the trigonometric relationship between the sides of a right-angled triangle formed while learners quietly copied notes. Step by step, he demonstrated worked examples while carefully guiding procedures for identifying the sides of a right-angled triangle formed from the observer's position to the object being viewed before applying trigonometric ratios. Throughout the lesson, the classroom remained silent, which he interpreted as attentiveness and understanding. After completing several examples, Mr. Karumaido summarized the key points and confidently concluded the lesson. He then assigned an extended activity consisting of three examination-style questions for further practice. However, as learners slowly packed their books, their passive engagement revealed an unspoken

expectation for participation, discussion, or an unanswered question, but no one dared ask any question because the teacher gave room for none. The following lesson, Mr. Karumaido walked into the classroom eager to review the extended activity he had assigned. To his satisfaction, every learner had attempted the three questions. However, as he quickly marked through their work, his confidence turned into disappointment. Most of the responses were incorrect. Learners had misidentified angles, applied the wrong trigonometric ratios, and drawn inaccurate diagrams despite what he believed had been a clear and thorough explanation.

some of the responses



Interpreting the outcome as carelessness and lack of seriousness, Mr. Karumaido resolved to punish the class for poor performance. Just as he was about to administer punishment, a learner timidly raised his hand. It was unusual—no learner had volunteered to speak during his lessons.

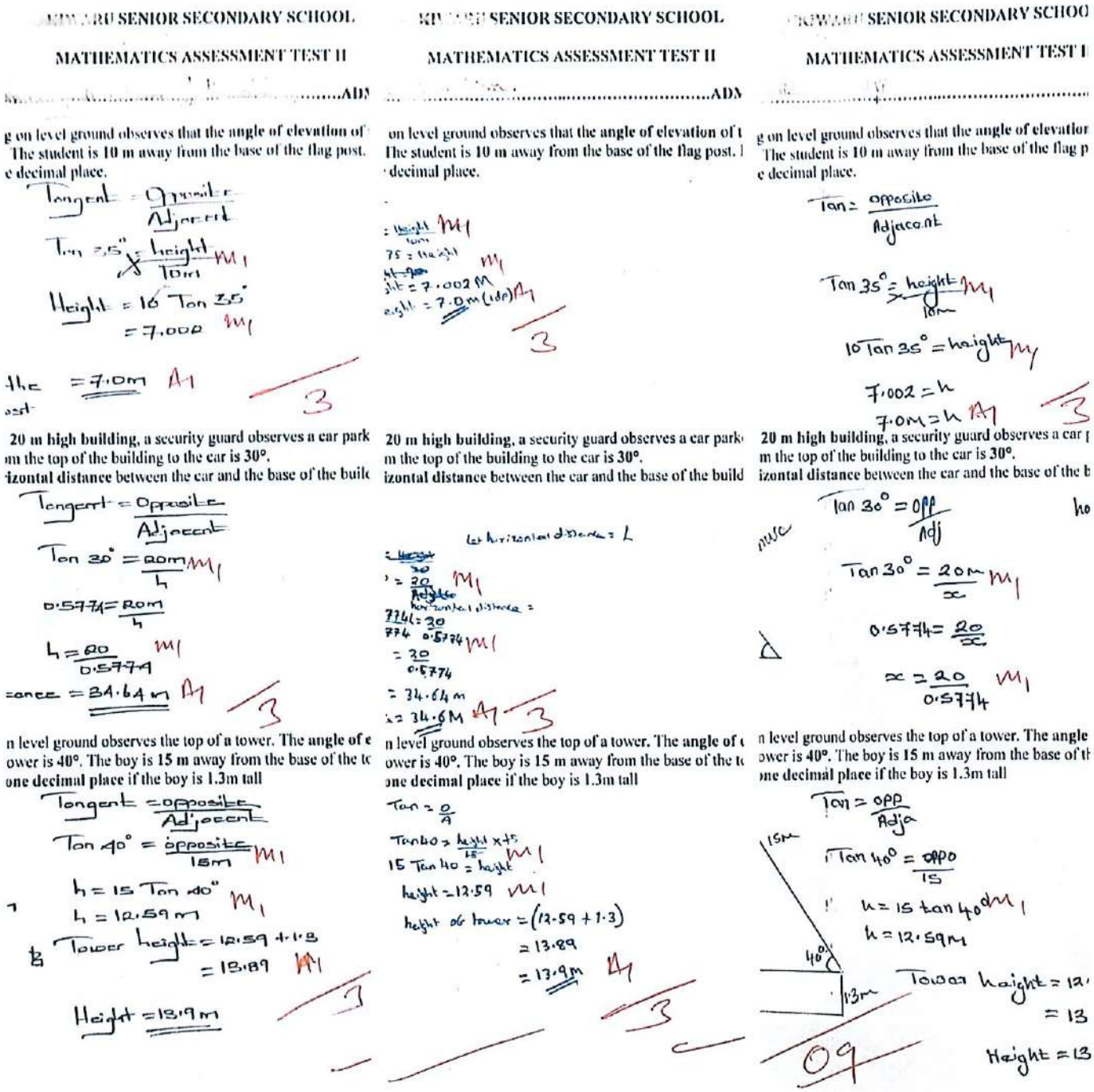
After a brief hesitation, Mr. Karumaido allowed him to talk. The learner asked, *"Sir, when you talk about the observer, do you assume his eyes are at the toes? Because you have been measuring the angles from the ground."*

This question instantly unsettled Mr. Karumaido. For many years, no student had ever questioned his explanations or his instructional approach. He felt challenged and almost confronted. Irritation replaced composure as he perceived the inquiry as disrespect rather than curiosity. Yet the classroom fell unusually attentive. After a short reflection, he realized that the learners' errors were not the result of laziness but possibly a conceptual misunderstanding rooted in how the lesson had been presented. During tea break, Mr Karumaido enquired from Madam Chika, a mathematics teacher, they were co-teaching, about the classroom. She praised the learners for always being attentive and active participants in her lessons. This confused Mr. Karumaido the more. Following this unsettling classroom experience, Mr. Karumaido sought further guidance and consulted me in my capacity as the Head of the Mathematics Department. Concerned by the clear gap between his teaching and the learners' understanding, we agreed that the matter required broader departmental reflection. Consequently, a departmental meeting was convened to examine the pedagogical approaches used in CBE, particularly in the teaching of mathematics. During the meeting, attention was drawn to the expectations of Competency-Based Education (CBE), which redefine the teacher's role from a transmitter of knowledge to a facilitator of learning. It was agreed that teachers should actively engage learners through questioning, discussion, collaboration, and exploration of ideas. The meeting provided a critical platform for reflecting on classroom practice, emphasizing that meaningful learning in CBE requires learners's participation, conceptual exploration, and opportunities for learners to construct understanding rather than passively receive procedures. This collective reflection helped situate Mr. Karumaido's classroom incident within the broader transition from traditional teacher-centered instruction to learner-centered pedagogical practice.

Reconstructing Teacher Identity

After reflecting deeply on the resolution of the departmental meeting, Mr. Karumaido resolved to re-teach the concept using a different approach that would actively involve learners in the learning process. In the subsequent lesson, he reorganized the class into small discussion groups

and presented them with practical tasks requiring them to draw diagrams, identify the position of the observer, and determine how angles of elevation and depression are correctly measured. He moved from group to group, listening to learners' discussions, posing guiding questions, and helping them clarify their reasoning. As learners debated their ideas and compared their diagrams, several misconceptions that had appeared in the previous assignment began to surface. Mr. Karumaido used these moments to guide learners toward correct interpretations. Through group presentations, learners gradually reconstructed the concept more accurately, transforming the previously silent classroom into an active environment of inquiry, collaboration, and conceptual understanding. The learners were given an extended activity, which they did very well. Some of the results are as shown below.



KIWARU SENIOR SECONDARY SCHOOL

MATHEMATICS ASSESSMENT TEST II

.....ADM

g on level ground observes that the angle of elevation of
The student is 10 m away from the base of the flag post.
e decimal place.

Tangent = Opposite / Adjacent

Tan 35° = height / 10m M1

Height = 10 Tan 35°

= 7.002 M1

the = 7.0m A1

3

20 m high building, a security guard observes a car park
m the top of the building to the car is 30°.
izontal distance between the car and the base of the buil

Tangent = Opposite / Adjacent

Tan 30° = 20m / h M1

0.5774 = 20m / h

h = 20 / 0.5774 M1

tance = 34.64 m A1

3

n level ground observes the top of a tower. The angle of e
ower is 40°. The boy is 15 m away from the base of the to
one decimal place if the boy is 1.3m tall

Tangent = opposite / Adjacent

Tan 40° = opposite / 15m M1

h = 15 Tan 40° M1

h = 12.59 m

Tower height = 12.59 + 1.3

= 13.89 A1

Height = 13.9 m

3

KIWARU SENIOR SECONDARY SCHOOL

MATHEMATICS ASSESSMENT TEST II

.....ADM

on level ground observes that the angle of elevation of t
The student is 10 m away from the base of the flag post.
decimal place.

= height / 10m M1

75 = height M1

ht = 7.002 M

eight = 7.0m (1dp) A1

3

20 m high building, a security guard observes a car park
m the top of the building to the car is 30°.
izontal distance between the car and the base of the build

Let horizontal distance = L

= 20 / Adjacent M1

horizontal distance =

774L = 30 / 774 0.5774 M1

= 30 / 0.5774

= 34.64 m

= 34.6M A1

3

n level ground observes the top of a tower. The angle of
ower is 40°. The boy is 15 m away from the base of the t
one decimal place if the boy is 1.3m tall

Tan = O / A

Tan 40 = height / 15 × 15 M1

15 Tan 40 = height

height = 12.59 M1

height of tower = (12.59 + 1.3)

= 13.89

= 13.9m A1

3

KIWARU SENIOR SECONDARY SCHOO

MATHEMATICS ASSESSMENT TEST I

g on level ground observes that the angle of elevatior
The student is 10 m away from the base of the flag p
e decimal place.

Tan = opposite / Adjacent

Tan 35° = height / 10m M1

10 Tan 35° = height M1

7.002 = h

7.0m = h A1

3

20 m high building, a security guard observes a car
m the top of the building to the car is 30°.
izontal distance between the car and the base of the b

Tan 30° = opp / Adj

Tan 30° = 20m / x M1

0.5774 = 20 / x

x = 20 / 0.5774 M1

n level ground observes the top of a tower. The angle
ower is 40°. The boy is 15 m away from the base of th
one decimal place if the boy is 1.3m tall

Tan = opp / Adja

Tan 40° = oppo / 15

h = 15 tan 40° M1

h = 12.59m

15m

40°

1.3m

Tower height = 12.

= 13

Height = 13

09

This classroom incident marked a profound professional awakening for Mr. Karumaido compelling him to reassess his long-standing beliefs about teaching and learning. Under the 8.4.4 curriculum, his identity as a teacher was anchored on authority, mastery of content, and control of classroom processes. Learning was perceived as successful when learners remained silent,

copied notes accurately, and reproduced them during examinations. The teacher dominated instruction while learners played a passive role as recipients of knowledge. Mr. Karumaido ultimately learned that effective teaching in CBE lies not in explaining more, but in creating environments where learners think, interact, and construct understanding together, signifying a transition from teaching for content coverage to teaching for competence development.

Conclusion

The classroom incident experienced by Mr. Karumaido illustrates how the transition from the 8.4.4 curriculum to Competency-Based Education (CBE) challenges long-established teacher identities and instructional practices. While traditional approaches emphasized content delivery, authority, and silent classrooms, the incident revealed that such methods may mask deep learner misconceptions. The experience demonstrated that meaningful understanding emerges when learners are actively involved in constructing knowledge through questioning, discussion, and collaboration. I therefore recommend that teachers continuously reflect on their classroom practices, embrace learner-centered pedagogical strategies, and create opportunities for dialogue and conceptual exploration. Additionally, schools should strengthen professional collaboration through departmental consultations, lesson reflections, and peer support to help teachers adapt to the facilitative role required in CBE. Such deliberate efforts can support teachers in reconstructing their professional identities while promoting deeper learner understanding and competence development in mathematics.

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Shift from Content-Based Learning to Competency-Based Learning: Experiences in Biological Specimen Collection and Preservation in Biology

Fridah Arimi

Abstract Competency-based education emphasises learner-centred activities, such as practical and group work, that foster knowledge retention rather than rote memorisation. For a long time, the education system has been based on memorisation, and very little of what is learnt is retained by learners. Learners have been forced to use various ways to cram concepts, including acronyms. This practitioner inquiry examines a Grade 10 biology lesson on specimen processing and preservation, a learner-centred activity. This was carried out in a public senior school in Meru, where I used a practical activity in a lesson on specimen processing and preservation. Different pedagogies were used, including collaborative and digital learning. I was also able to was able to carry out formative assessment during the lesson. The learners were actively interacting with each other, the digital apparatus, and the teacher. It was no longer a passive lesson, and it aligned with competency-based education (CBE), which advocates collaborative learning, critical thinking, and digital literacy. In conclusion, learners' retention was higher, and they participated actively throughout the lesson.

Key words: *Competency, Pedagogy, Digital literacy, Collaborative learning, Formative assessment acronyms*

1.0 Introduction

The introduction of CBE brought a paradigm shift from content learning to competency development UNESCO(2015). It shifted from teacher-centred to an emphasis on active participation, learner engagement in projects, group work, practical activities, and inquiry-based learning, where learners ask questions, investigate, and construct knowledge. Progress is measured by demonstration of skills rather than memorising content. This practitioner inquiry document is based on a grade 10 biology lesson. It shows a shift from content-based learning to competency-based development. This aligns with CBE exceptions.

CBE Framework and competencies in Biology

CBE aims to cultivate active participation of learners through experiments, projects and discussions. Working in groups during projects fosters communication and collaboration, as well as creativity and imagination, by encouraging the development of innovative conservation ideas. It also develops digital literacy through online research of biological information. Assessment practices prioritise formative approaches that document competency development through learner demonstration of a skill.

Context and problem statement

I am a Grade 10 biology teacher at a public school in Meru County. I had a class of 34 learners. Over time, I have been teaching the concept of specimen processing, and the learners have been using the previous system of 8.4.4, under which the curriculum did not require teachers to involve learners in specimen collection and preservation. The concept is taught in Grade 10, Strand: Biology and Biodiversity, Substrand: Specimen Collection and Preservation KICD(2025). Learners are expected to use basic local materials to *collect, process, and preserve* specimens for biological studies, including plants, small, non-lethal, locally available animals. However, I noted that the learners did not fully understand the types of specimen preservation methods or their importance. When I was an 8.4.4 teacher, this concept was purely left to laboratory technician to carry out on preservation of specimens.So the learners had very little knowledge of specimen preservation hence made it hard for the them to master the content.After attending a professional workshop [88]on implementing CBE, I drew on the knowledge I acquired and redesigned the lesson to improve learners' knowledge, skills, and attitudes in this area.

Methodology and Procedure

I carried out this activity during my biology lessons, combining practical skill assessment with my reflections and observations. In Competency-based education (CBE), learners are expected to demonstrate mastery of specimen preservation techniques and appreciate their importance. Participants for the class-based experience included students in grades 10, a sample of 34 learners. The unit of analysis was group and individual learner performance on specimen preservation tasks. I introduced the specimen-preservation method of dry mounting. I assigned learners to groups for hands-on practice and guided them through the dry-mounting step by step.

I collected the mounted specimens for evaluation, and I recorded the reflections. I analysed learners' group activities to determine skill mastery and the challenges they faced. Only the learners' work was photographed. The stinging insects were immobilised with diethyl ether, a safe reagent. The learners picked only a few specimens to conserve the environment.

Data Collection

Practical direct observation and demonstrations as learners performed the dry mounting of specimens of insects. Dry mounting techniques were adapted to prepare insects preserved in alcohol for long-term display Aguiar,

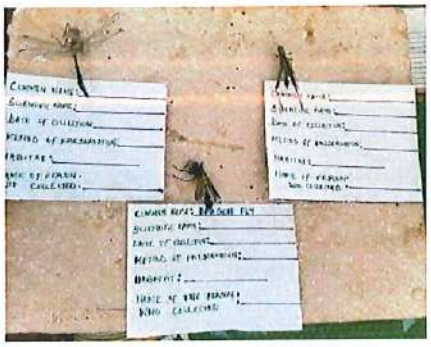
(2012). I used a checklist to record learner activities and competencies, focusing on the handling of apparatus and insects, including correct pin insertion, accurate labelling, accurate scientific naming, and safety. There were also learner reflections on the experience lesson and on other lessons, collected using a short questionnaire. Finally, I took photographs as photographic Evidence: the learners continued with their work.

Outcomes

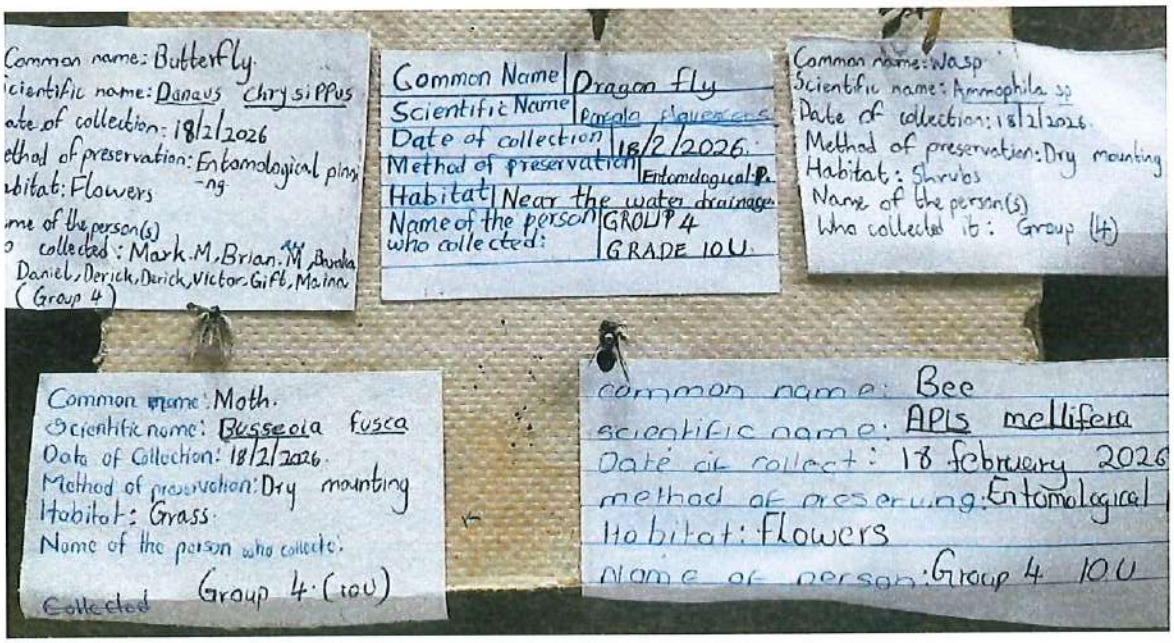
The lesson was so much more enjoyable when learners took part in specimen collection and preservation, which initially was the work of a laboratory technician. The learners demonstrated practical mastery of specimen preservation; they correctly pinned, labelled, and sorted the insect specimens with minimal guidance. The learners followed preservation procedures accurately, indicating acquisition of practical competency. The learner appreciated the importance of preservation. The specimens were well preserved for future use in another strand, for example, classification. The specimens will be intact then, with all the external features present, unlike the previous methods, where they were being preserved in containers with formalin.

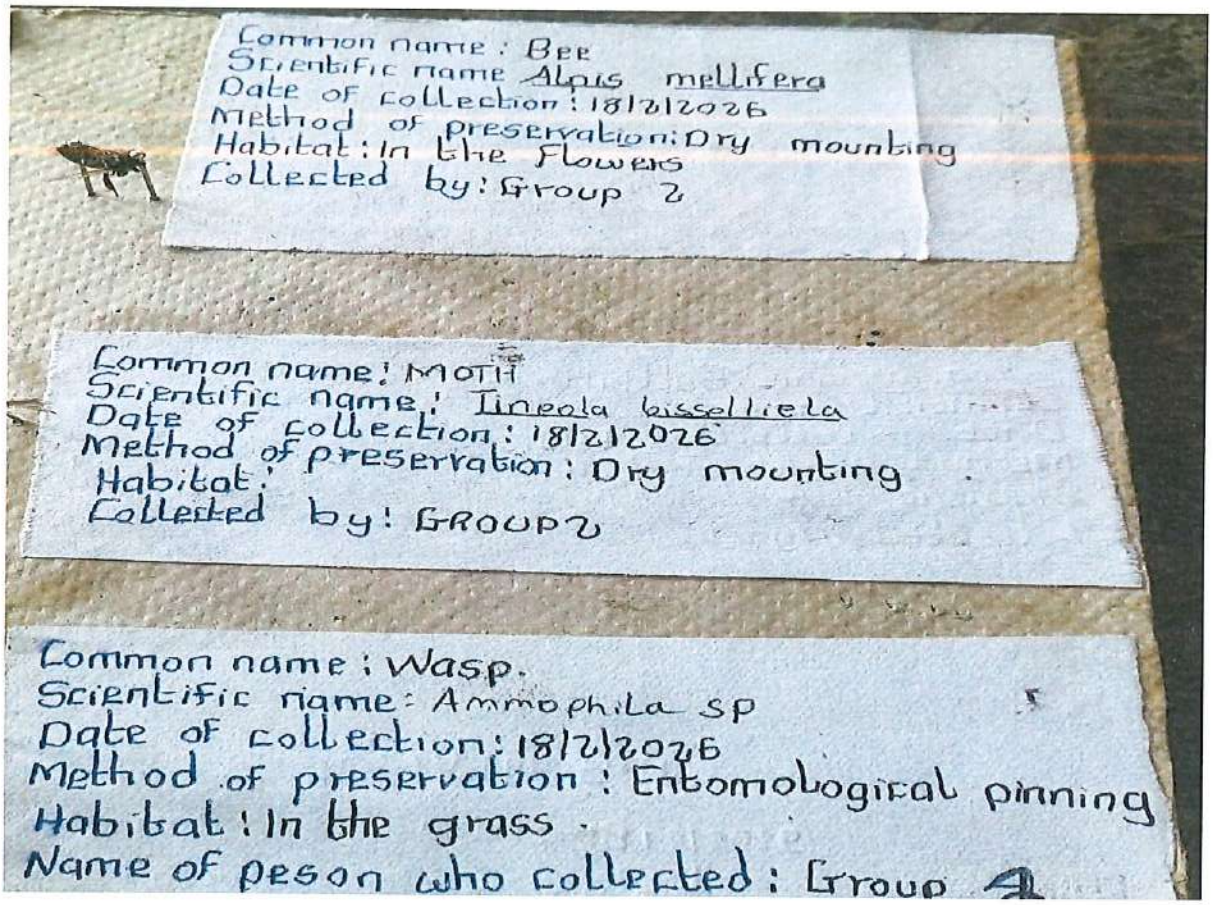
I picked some group activities and displayed them below.


COMMON NAME: DRAGON FLY
DATE OF COLLECTION: 18TH-FEB-2026
METHOD OF PRESERVATION: DRY MOUNTING
NAME OF THE PERSON COLLECTED: GROUP 1 (10U)
COMMON NAME: GRASSHOPPER
DATE OF COLLECTION: 18TH-FEB-26
NAME OF PERSON: GROUP 1 (10U)
COMMON NAME: WASP
SCIENTIFIC NAME: Ammophila sp
DATE OF COLLECTION: 18TH-FEB-2026
METHOD OF PRESERVATION: DRY MOUNTING
HABITAT: NEAR TREES
NAME OF PERSON: GROUP 1 (10U)





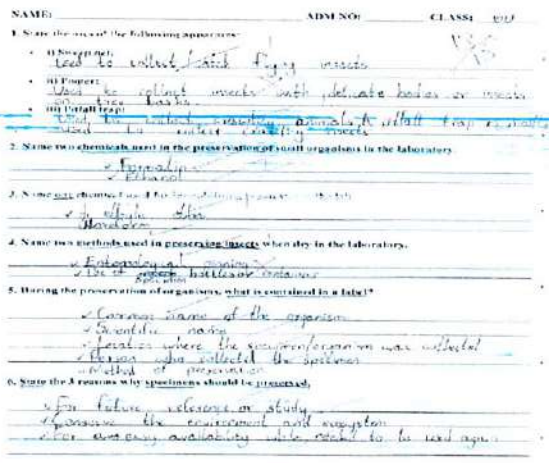

Common name: Butterfly
Scientific name: Danaus Chrysippus
Date of collection: 18/2/2026
Method of preservation: Entomological pinning
Habitat: Flowers
Name of the person(s) who collected: Mark.M, Brian.M, Bwoka Daniel, Derick, Darick, Victor, Gift, Maina (Group 4)
Common Name | Dragon fly
Scientific Name | Pantala flavescens
Date of collection | 18/2/2026
Method of preservation | Entomological P.
Habitat | Near the water drainage
Name of the person who collected: | GROUP 4 GRADE 10U.
Common name: Wasp
Scientific name: Ammophila sp
Date of collection: 18/2/2026
Method of preservation: Dry mounting
Habitat: Shrubs
Name of the person(s) who collected is: Group (4)
Common name: Moth.
Scientific name: Busseola fusca
Date of Collection: 18/2/2026
Method of preservation: Dry mounting
Habitat: Grass
Name of the person who collected: Group 4 (10U)
common name: Bee
scientific name: APIS mellifera
Date of collect: 18 february 2026
method of preserving: Entomological
Habitat: Flowers
Name of person: Group 4 10U

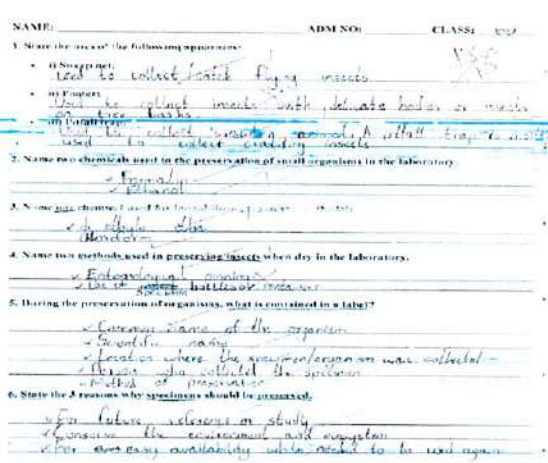


Afterwards, I picked 30 learners ,15 from form 3.8-4-4 class and 15 from CBE grade 10 class and gave them a a short test on the activity to assess their understanding of the process. I noted that CBE

learners achieved higher marks than those I had taught in previous system in the same context.This I attributed it to the practical skills that learners were engaged in unlike the previous system of education.At the end of the term, I also gave learners' reflection where the learners noted down on what they felt on the learning experience.

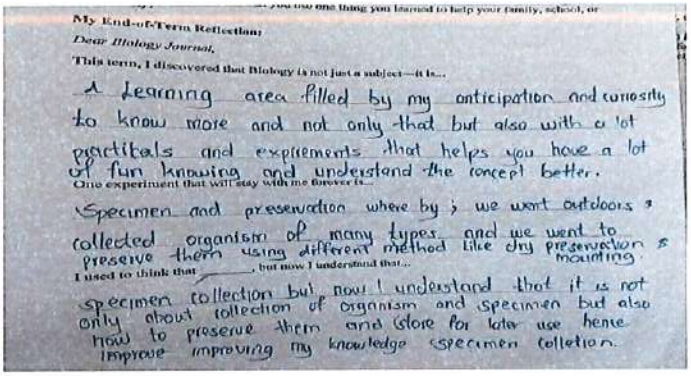
Below are samples of the test and the scores.





I took a sample of 30 learners.15 from 8-4-4 and 15 from CBE.
From the marked samples above,the average score for 8-4-4 was 7/15 and CBE was 13/15.

Some of the learners' reflections


My End-of-Term Reflection

Dear Biology Journal,

This term, I discovered that Biology is not just a subject—it is...

A learning area filled by my anticipation and curiosity to know more and not only that but also with a lot practitals and experiements that helps you have a lot of fun knowing and understand the concept better.

One experiment that will stay with me forever is...

Specimen and preservation where by ; we went outdoors & collected organism of many types and we went to preserve them using different method like dry preservation & mounting.

I used to think that _____, but now I understand that...

specimen collection but now I understand that it is not only about collection of organism and specimen but also how to preserve them and store for later use hence improve improving my knowledge specimen collection.


8-4-4

NAME: _____ ADM NO: _____ CLASS: _____

1. State the uses of the following apparatus:

- i) Sweep net:
- ii) Pooter:
- iii) Pitfall trap:

2. Name two chemicals used in the preservation of small organisms in the laboratory.

3. Name one chemical used for immobilizing organisms in the lab.

4. Name two methods used in preserving insects when dry in the laboratory.

5. During the preservation of organisms, what is contained in a label?

6. State the 3 reasons why specimens should be preserved.


NAME: _____ ADM NO: _____ CLASS: _____

1. State the uses of the following apparatus:

- i) Sweep net:
- ii) Pooter:
- iii) Pitfall trap:

3. Name one chemical used for immobilizing organisms in the lab.

4. Name two methods used in preserving insects when dry in the laboratory.

5. During the preservation of organisms, what is contained in a label?

6. State the 3 reasons why specimens should be preserved.

Discussion

This experience showed me that involving learners directly in specimen collection and preservation could enhance their practical mastery, collaboration, learner motivation, and eventual concept retention. The findings suggest that practical engagement in an authentic task, in this case specimen collection, processing and preservation, enabled learners to construct knowledge actively rather than rely on rote learning. This supports the principles of Competency-Based Education, which emphasise the demonstration of skills, inquiry, and learner participation, and represents a departure from my former practice, even in the same topic where learners study this method in theory. The study found that learners correctly pinned, labelled, and sorted specimens with minimal guidance, demonstrating acquisition of practical competencies. This finding agrees with studies that emphasise the value of school specimen preservation in

supporting long-term biological observation, classification skills, and practical science learning. Aguiar (2012) observed that proper dry-mounting techniques preserve insect specimens effectively for future scientific study and educational use. Furthermore, UNESCO (2015) emphasises that competency-based science learning should involve practical activities that develop inquiry skills, collaboration, and problem-solving competencies.

Another experience was an opportunity to conduct deeper, continuous formative checks of the learner's ability to demonstrate science process skills. The learner's ability to select suitable, mountable specimens based on external physical structures and to discuss the process of drying and pinning the specimens is not easily tested in a test or exam, but the practical work gave me this opportunity.

Conclusion and implications for Practice

This experience demonstrated to me that the Competency-Based Education (CBE) approach enhances practical skill development in biology. Learners successfully acquired hands-on skills in specimen preservation, including proper pinning, handling, and labelling techniques. Allowing learners to interact in groups and manipulate real biological specimens, rather than relying solely on theoretical explanations, can improve engagement, conceptual understanding, and long-term retention of biological concepts. Incorporating formative assessment during practical activities, demonstrations, and questioning enabled me to continuously monitor competency development and provide effective, immediate feedback. The use of digital tools requires more training for my learners and me, including access to more digital resources and the internet.

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Optimization of linear programs: Use of alternative method in teaching Mathematics.

Nathan Oigo Mokaya

Abstract The article demonstrates my experience as a mathematics teacher, the challenges I encountered while guiding my learners on how to graph linear programs and optimizing them. The traditional method available to optimize a linear program is that of search line. Search line method involves sliding a setsquare along the straight drawn using objective function until an optimal point is reached. I faced quite a number of challenges while guiding my students on how to use search line approach to optimize a linear program. To address those challenges, I shifted to use of vertex co-ordinates as an alternative approach in teaching optimization of linear programs. Therefore, in this article, I have documented the use of vertex co-ordinates to optimize a linear program as an alternative approach to settling this challenge. The vertex method was lauded by majority of the students because it is practical and easy to use. The use of vertices coordinates to maximise or minimise linear programs is highly recommended because it is simpler and straight forward to use and it also widens the scope of teaching and learning programming away from traditional use of search lines.

Keywords: Search line, linear program, optimization, and vertices co-ordinates.

Introduction

Maximising and minimising (optimising) is a concept taught in form four in the Kenya secondary school curriculum under the area called linear programming. This area involves determining the solution which will maximise or minimise a given objective function of the linear program. The use of search line to maximise or minimise the objective function is commonly used. However, most students had a challenge in coming up with the search line and sliding of the set square to achieve the desired outcome. The use of search line to optimize the

objective function is the only method used in our curriculum. This monotonous approach in teaching optimization of linear programs has made this area unpopular to most learners. The use of alternative approaches when teaching mathematics is highly productive and mostly alters the altitude of learners towards learning mathematics (Kunwar and Sopkota, 2022). In this article I reflect on how I used the vertices co-ordinates as an alternative approach in teaching optimization of a linear program.

Concept of Linear Programming

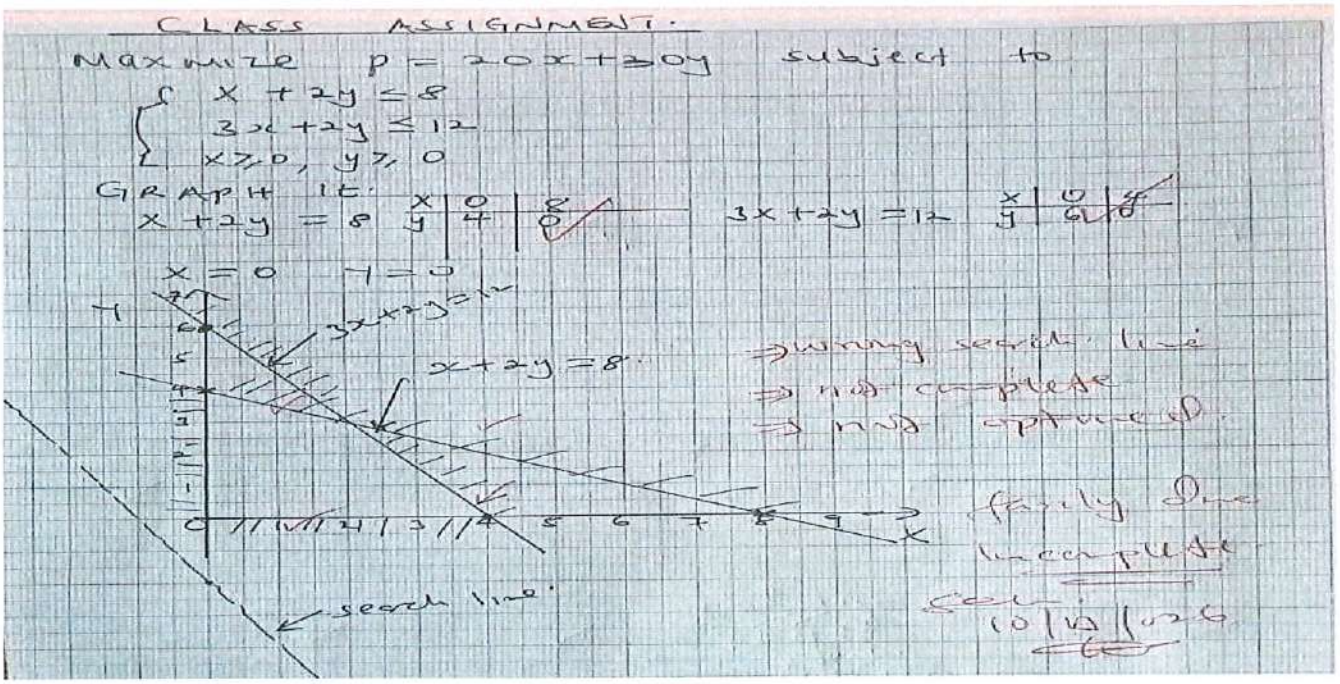
Generally linear programming is a process that involves forming the inequalities that satisfies a given condition, formulating an objective function, graphing the inequalities and finally optimizing the objective function. Linear programming is a mathematical technique used to find the best possible outcome such as maximum profit or minimum cost under a set of conditions. This area is important in our daily life where resources are limited but their uses need to be optimized. For instance, linear programming is mostly applied transport, industries and more other fields (Kunwar and Sopkota, 2022).

How I Taught the Concept of Optimization to my Class.

There are two approaches used to optimize a linear program, the use of search line and use of vertex co-ordinates. Traditionally, the use of search line is widely used and emphasised. There was this evening I was busy guiding my learners in class on how to optimize a linear program. As usual I guided them on how to optimize the linear program using the search line method. However, some learners were stuck and could not draw the search line or even locate it (' *'how do we get the search line*?'' I could hear the murmurs). Other students were unable to align the ruler and setsquare on the search line and slide it (*how do we arrange the setsquare and the ruler on the searching line*? I could hear this form of questions from a number of groups as I moved around). I demonstrated repeatedly on how to draw the search line and use it to optimize a linear program. However, in a class test I could observe a struggle in locating the search line as well as sliding the set square to optimize the linear program. Majority of my students were unable to draw the search line as well as arranging the ruler and the setsquare (see figure 1).

Figure 1

Sample of response I got while emphasising the use of search line.



Futhermore, the course book recommended for use has no pictorial diagram showing how the ruler and the setsquare are or should be arranged and how sliding is done. This actually worsen the understanding of otimization using search line.

To address this challenge, I shifted to vertex co-ordinates as an alternative method of optimizing the objective function. Vertex co-ordinates method is a simplified extension of search line method.

How Vertex Co-Ordinates Method Worked in my Class.

Vertex co-ordinates method uses the co-ordinates of vertices to optimize linear programs. If a linear program has a solution, it will always occur at the vertex of the feasible region. If there are multiple solutions, at least one of them will occur at a vertex. To achieve this, I gave out an example, which we worked out together by determining the vertex co-ordinates of the feasible region. We solved the system of equations consisting of the lines whose intersection is the vertex. We then evaluated objective function to be optimized at each vertex. Finally we identified the maximum or minimum value of the objective function. To my surprise, the interest

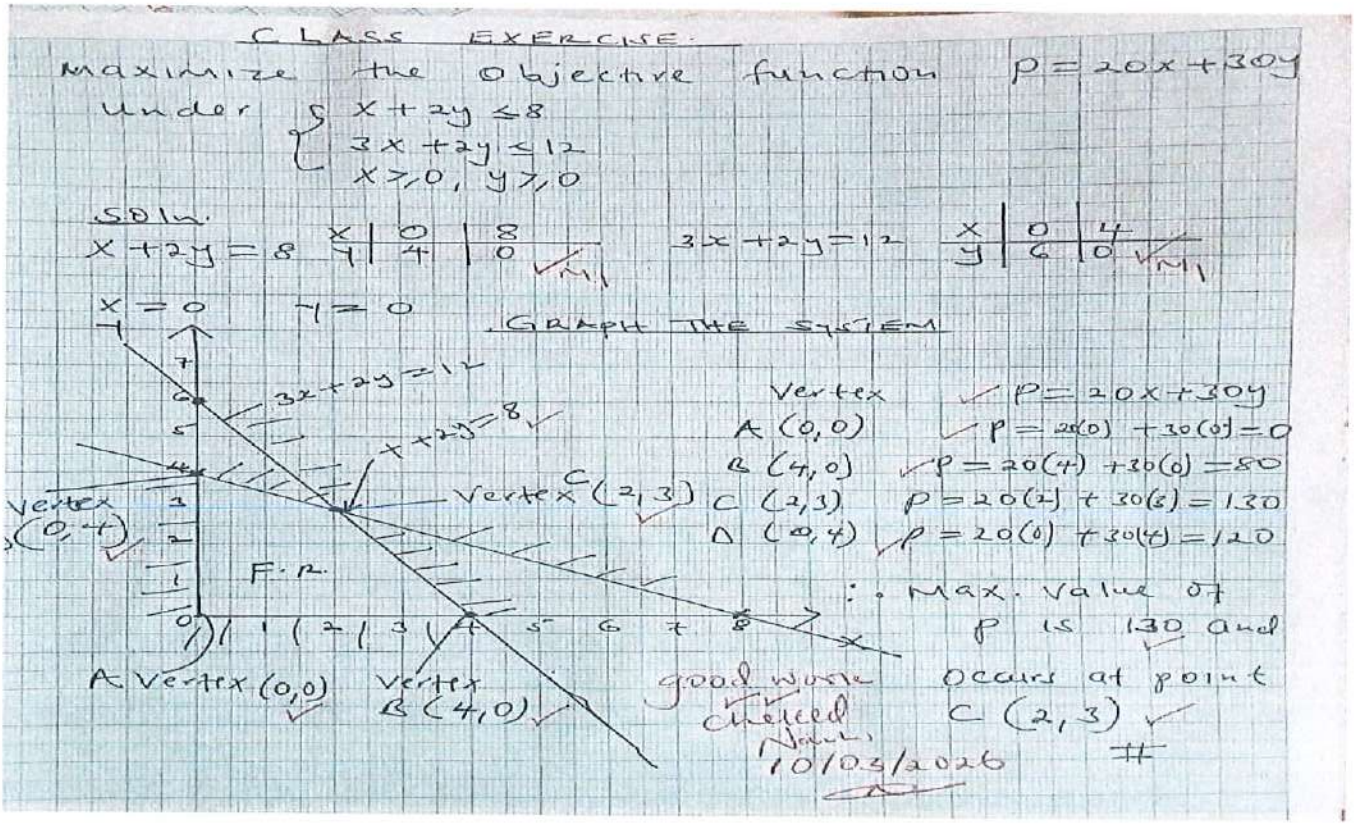
of my learners towards optimization was ignited; I could observe the satisfaction and excitement as they worked out class exercises in their groups.

I then gave out this class test

Determine the values of x and y that will maximize the objective function $p = 20x + 30y$ under the constrains $\begin{cases} x + 2y \leq 8 \\ 3x + 2y \leq 12 \\ x \geq 0, y \geq 0 \end{cases}$

Figure 2

Sample response obtained after I used vertex co-ordinates as an alternative teaching method.



Responses of learners

The students were free to use any of the two approaches to optimize linear programs. To my surprise out of a class of 52 students, 48 students used vertex co-ordinates to optimize the linear programs with ease. The remaining 4 students were top students in the class and used both search

line and vertex co-ordinates to optimize the linear programs. The shift of students' altitude to this learning area was wonderful. Seeing my students asking for more tests in this learning area was amazing and fulfilling. Every learner is unique; therefore, as teachers of mathematics let us diversify our instructional approaches in order create opportunities for each student to understand concepts in a way that resonate with them. Teachers of mathematics should embrace alternative approach that work best for their learners and avoid sticking to traditional method which may not be working for majority of learners.

Conclusion

Mathematics learning become interesting when there are alternatives approaches in use. In this article, I have reflected on how I used vertex co-ordinates method as an alternative approach to optimize a linear program. Vertex co-ordinates approach is a simplified method used to optimize linear programs. To use this method, you need to read the vertex co-ordinates and replace them in objective function to be optimized. By use of vertex co-ordinates to optimise a linear program, it gave the learners alternative cheaper and quick approach in overcoming challenges associated with search line approach. Additionally, this approach motivated learners who had already given up in this learning area and mathematics in general. I therefore recommend exploring of alternative approaches when teaching and learning of mathematics in different learning areas to beef up learning and interest of learners.

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Enhancing Spatial Reasoning in Secondary School Three-Dimensional Geometry Through Guided Model Analysis and Digital Visualization.

By Edward Solol

Abstract Three-Dimensional Geometry remains one of the most challenging topics in secondary school mathematics because learners often experience difficulties in visualizing spatial relationships, interpreting projections, and identifying geometric structures represented in two-dimensional diagrams. These challenges frequently result in poor problem-solving performance and overreliance on memorized procedures rather than conceptual understanding. This study investigated the effectiveness of guided model analysis and digital visualization in enhancing learners' spatial reasoning in Three-Dimensional Geometry. The study adopted a classroom-based action research design involving 75 Form Four learners at Talek Boys Secondary School. Data were collected through diagnostic assessments, post-intervention assessments, and classroom observations. Quantitative data were analyzed using descriptive statistics, specifically frequencies and percentages, while classroom observations were used to support interpretation of learner progress and engagement. The intervention combined guided exploration of physical geometric models, use of cardboard overlays and strings to represent spatial relationships, and reinforcement through GeoGebra 3D. Findings revealed substantial improvement in learners' understanding of key geometric concepts. The proportion of learners correctly identifying space diagonals increased from 26.7% to 80.0%, while those correctly determining angles between planes increased from 20.0% to 66.7%. Learners also demonstrated increased confidence, improved engagement, and greater ability to justify their reasoning when solving geometry problems. The study concludes that integrating guided model analysis with digital visualization can significantly enhance learners' spatial reasoning, conceptual understanding, and problem-solving abilities in geometry. The findings support the use of visualization-rich instructional approaches in improving mathematics teaching and learning.

Keywords: *Digital Visualization, GeoGebra, Spatial Reasoning, Three-Dimensional Geometry, Action Research*

Introduction

Three-Dimensional Geometry is widely regarded as one of the most conceptually demanding topics in secondary mathematics because learners must mentally manipulate spatial relationships that are not directly observable on two-dimensional representations. Large-scale assessments conducted by the Organisation for Economic Co-operation and Development (OECD, 2019) continue to highlight persistent challenges in mathematical reasoning and problem solving. Research further underscores the foundational role of spatial thinking in geometry learning and broader STEM achievement (Newcombe, 2017).

Despite this evidence, classroom practice often remains formula-driven, with learners prioritizing memorized procedures over relational understanding. Constructivist theory, as advanced by Piaget (1970), emphasizes that knowledge is actively constructed through meaningful engagement. Similarly, Sweller's Cognitive Load Theory (1988) highlights the importance of structured scaffolding when learners encounter cognitively demanding tasks. Multimedia learning principles articulated by Mayer (2020) further suggest that coordinated visual supports enhance conceptual processing when appropriately sequenced.

Recent studies continue to demonstrate the effectiveness of visualization-rich learning environments in enhancing learners' spatial reasoning and geometric understanding. Putra et al. (2023) found that GeoGebra-assisted exploration of three-dimensional shapes strengthened mathematical reasoning and learners' ability to justify geometric relationships through informal proof construction. A systematic review by Muslim et al. (2023) concluded that GeoGebra positively influences mathematics learning outcomes by enhancing conceptual understanding, problem-solving skills, and visualization of abstract mathematical concepts. More recently, Gurmu et al. (2024) reported significant gains in learners' conceptual understanding of geometry through GeoGebra-assisted instruction. These studies provide strong empirical support for integrating dynamic digital visualization tools into geometry instruction and reinforce the rationale for the present intervention.

Guided by these theoretical perspectives, this classroom-based intervention sought to strengthen spatial reasoning through structured model analysis and layered visualization strategies.

Problem Statement

Despite classroom instruction, many secondary school learners continue to experience difficulties in visualizing and interpreting spatial relationships in Three-Dimensional Geometry. Preliminary classroom assessments revealed persistent challenges in identifying space diagonals, determining angles between planes, constructing projections, and interpreting relationships among geometric elements. Learners frequently relied on memorized formulas rather than conceptual understanding, resulting in errors when solving examination-style problems. These challenges highlighted the need for an instructional intervention that would strengthen learners' spatial reasoning through guided model analysis and digital visualization.

Purpose and Objectives of the Study

The purpose of this study was to investigate the effectiveness of guided model analysis and digital visualization in enhancing learners' spatial reasoning in Three-Dimensional Geometry.

The study was guided by the following objectives:

1. To determine the effectiveness of guided model analysis in improving learners' understanding of spatial relationships in Three-Dimensional Geometry.
2. To examine the contribution of digital visualization using GeoGebra 3D in enhancing learners' interpretation of geometric relationships.
3. To explore changes in learners' confidence and problem-solving approaches following participation in the intervention.

Research Methodology

Research Design

The study adopted a classroom-based action research design. Action research was appropriate because it enabled the teacher to identify a learning challenge, implement an instructional intervention, evaluate its effectiveness, and reflect on classroom practice within a natural learning environment.

Participants

The study involved seventy-five Form Four learners from Talek Boys Secondary School. The participants had previously covered Three-Dimensional Geometry but continued to experience difficulties in solving problems involving spatial relationships.

Data Collection

Data were collected through diagnostic assessments, post-intervention assessments, and classroom observations. The diagnostic assessment established learners' baseline understanding of spatial concepts, while the post-intervention assessment evaluated changes in performance following the intervention. Classroom observations were conducted throughout the intervention to monitor learner engagement, participation, and problem-solving approaches.

Data Analysis

Data obtained from the diagnostic and post-intervention assessments were analyzed using descriptive statistics, specifically frequencies and percentages. Learner performance before and after the intervention was compared to determine changes in their ability to identify space diagonals and determine angles between planes. The results were presented in tables and interpreted to assess the effectiveness of the intervention. Classroom observations made during the intervention were used to support the interpretation of the quantitative findings by providing insights into learner engagement, participation, confidence, and problem-solving approaches.

Ethical Considerations

Permission to conduct the study was obtained from the school administration. Participation occurred within normal classroom instructional activities and no learner was disadvantaged. Learner identities were protected and all information collected was used solely for educational and research purposes. The study adhered to principles of academic integrity and originality.

Intervention Process

The intervention unfolded in three structured phases.

Phase 1: Guided Model Analysis

Learners examined pre-constructed solid models and were guided to:

- Project a line onto a plane using string alignment.
- Identify the shortest distance between skew lines.
- Trace intersection lines between two planes.
- Construct right-angled triangles formed through projection.

Learners were prompted with structured questions:

- Where is the projection?
- Which triangle represents the true angle?
- What is the line of intersection between these two planes?

This questioning shifted attention from procedural execution to spatial reasoning.

Phase 2: Cardboard Overlays and String Visualization

Cardboard overlays were used to isolate specific planes when determining:

- The angle between a line and a plane.
- The angle between two planes.

Learners physically folded cardboard planes along intersection lines to visualize angles between planes. Strings represented skew lines and space diagonals. By adjusting string alignment, learners observed how projecting a line onto a parallel plane generated a measurable angle.

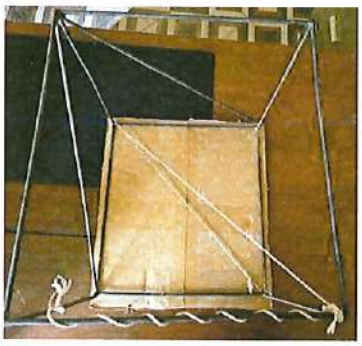

Figure 1: Top view of the cube model showing internal diagonal alignment



Figure Front view of the cube model with diagonal connections

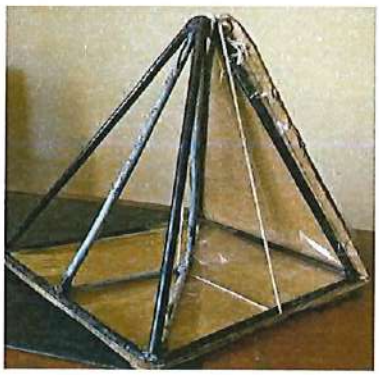

Figure 3: Side view of the pyramid model forming triangular structure

Through tactile manipulation, learners clarified that:

- The angle between skew lines is determined through parallel projection.
- The angle between a line and a plane is measured between the line and its projection.

- The angle between two planes is measured along their line of intersection.

Phase 3: Digital Reinforcement Using GeoGebra 3D

After physical exploration, learners manipulated virtual solids using GeoGebra 3D. Rotating figures and revealing hidden lines reinforced relationships previously observed physically, aligning with multimedia learning principles (Mayer, 2020). By dynamically rotating solids, learners observed embedded right-angled triangles from multiple perspectives and confirmed the accuracy of constructed projections.

Hidden edges and internal diagonals were revealed to make internal structures visible, strengthening connections between concrete manipulation and abstract reasoning. This progression from tactile exploration to digital visualization consolidated spatial understanding while reducing reliance on memorized procedures.

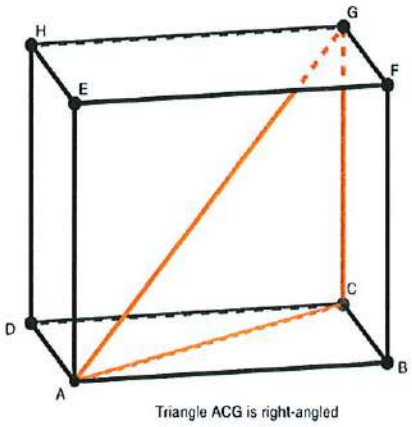

Figure 4: Embedded triangle front view

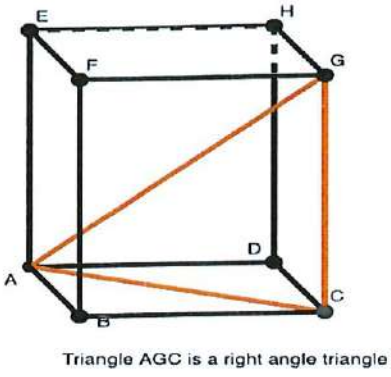

Figure 5: Embedded triangle side view

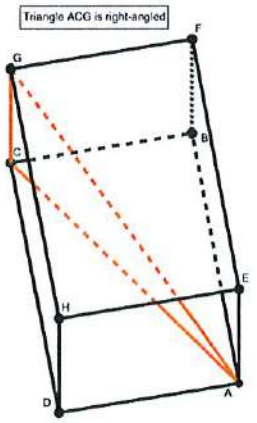

Figure 6: Embedded triangle top view

Findings

The intervention resulted in notable improvements in learners' spatial reasoning and problem-solving abilities. Comparison of diagnostic and post-intervention assessment results revealed significant gains in learners' ability to identify spatial relationships and construct appropriate geometric representations.

Table 1

Performance Before and After the Intervention

Spatial Reasoning Skill	Before Intervention	After Intervention
Correct identification of space diagonals	20/75 (26.7%)	60/75 (80.0%)
Correct determination of angles between planes	15/75 (20.0%)	50/75 (66.7%)

The results indicate substantial improvement across both assessed competencies. The proportion of learners correctly identifying space diagonals increased by 53.3 percentage points, while the proportion correctly determining angles between planes increased by 46.7 percentage points. These gains suggest that guided model analysis and digital visualization strengthened learners' ability to interpret spatial relationships and construct appropriate geometric representations.

Post-intervention responses further revealed increased confidence in solving examination-style geometry problems. Learners demonstrated greater accuracy in identifying internal right-angled triangles and were more likely to construct auxiliary projections before performing calculations. Classroom interactions also indicated growing confidence and conceptual clarity. One learner noted, *"Before, I just looked for a formula, but now I first try to see the triangle inside the shape."* Another explained, *"The angle is not on the surface, you have to create it. That's what I was missing."*

These responses suggest that learners were actively constructing and interpreting spatial relationships rather than relying on memorized procedures.

Reflection

A key conceptual breakthrough emerged during the physical projection activity using strings, where learners began to recognize the necessity of constructing a parallel line and forming a right-angled auxiliary triangle to make sense of spatial relationships. This marked a shift from intuitive guessing to more deliberate geometric reasoning. The use of cardboard to isolate planes further clarified the concept of angles between planes, as it allowed learners to visually and physically separate intersecting surfaces. Classroom observations indicated that learners became more confident in solving such problems once they could identify the line of intersection as a reference point for determining the angle between planes. The integration of projection, auxiliary

construction, tactile verification, and digital rotation created a multi-representational learning experience that reduced guesswork and encouraged more precise geometric justification.

Discussion

The findings suggest that structured physical engagement, when combined with digital reinforcement, can significantly enhance learners' spatial reasoning in geometry. By actively manipulating models and then verifying their observations through dynamic visualization, learners were better able to connect concrete experiences with abstract geometric principles. This finding is consistent with recent studies that highlight the effectiveness of GeoGebra-assisted visualization in strengthening spatial reasoning and conceptual understanding in geometry (Gurmu et al., 2024; Putra et al., 2023). The intervention supported the development of deeper conceptual understanding rather than procedural recall alone. Furthermore, visualization-rich instruction offers a practical strategy for examination-focused classrooms, as it not only improves problem-solving accuracy but also strengthens learners' ability to justify their reasoning. Such integration of hands-on and digital methods highlights a balanced instructional approach that is both accessible and pedagogically effective.

Conclusion

Guided model analysis combined with structured visualization strategies significantly strengthened learners' understanding of Three-Dimensional Geometry. By prioritizing projection reasoning before formal formula derivation, learners developed deeper conceptual clarity, stronger justification skills, and increased confidence in solving examination-style problems. Teachers are therefore, encouraged to integrate structured visualization activities such as plane isolation, projection tracing, and guided model analysis prior to symbolic derivations in order to promote robust geometric reasoning and reduce formula dependency.

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Marble and Rice Model: A Practical Approach to Teaching Metallic Bonding

By Martha Nasimiyu Namasake

Abstract

Metallic bonding is a challenging concept for many learners due to its abstract nature involving positively charged metal ions and delocalized electrons. This article presents a classroom-based instructional innovation using locally available materials—glass marbles and rice grains—to support learners' understanding of metallic bonding. The innovation emerged from reflective practice after observing persistent learner misconceptions and low engagement during lessons. The model uses marbles to represent metal ions arranged in a lattice and rice grains for delocalized electrons. Learners physically manipulated the materials to simulate electron movement and explain metallic properties such as conductivity, malleability, and ductility. Implementation of the model resulted *in an increase in the mean score of responses from 50.25% to 69.00% before and after use of the model respectively. Notable* improvements were also observed in learner participation, clearer conceptual explanations, and better performance in follow-up assessments. This article examines the efficacy of low-cost hands-on strategies that make abstract chemistry concepts more accessible and meaningful to learners. It also provides practical insights for teachers seeking to enhance learner engagement and understanding in senior school chemistry

***Keywords**: Delocalized Electrons, Metallic Bonding, Model-Based Learning, Teaching Innovation*

Introduction

Understanding metallic bonding is essential for explaining the structure and properties of metals in senior school chemistry. However, the concept is often difficult for learners because it involves microscopic particles that cannot be directly observed. Learners are expected to understand that metals consist of positively charged ions arranged in a lattice and surrounded by a "sea" of delocalized electrons that move freely throughout the structure (Atkins & de Paula, 2018).

In my classroom, I observed that many learners struggled with this concept. They often confused metallic bonding with ionic bonding, assumed that metals consist of neutral atoms, or believed

that electrons belong to specific atoms rather than being shared across the structure. As a result, they found it difficult to explain properties such as electrical conductivity, ductility, and malleability. Lessons relied mainly on verbal explanations and textbook diagrams could not sufficiently address these misconceptions.

Learners' misconceptions in sciences constitute a major concern to researchers, science teachers, students and the industry as a whole (Soeharto & Csapó, 2022; Suparman, Rohaeti, E., & Wening, 2024). Research indicates that students' performance in science subjects especially in chemistry has been poor and attributed to the lack of practical experience during teaching (Boachie, Quansah, & Asano, 2023). According to Tampubolon and Sudrajat (2024), effectively utilizing learning models is highly likely to improve students' learning outcomes.

Research in chemistry education further demonstrates that learners understand abstract concepts better when they are supported by models and hands-on experiences (Johnstone& El-Banna, 2018).This aligns closely with Competency-Based Education (CBE), which emphasizes learner-centred approaches and active engagement. Grounded in this framework, I sought to develop a simple, practical model using locally available materials to make metallic bonding more concrete.

This article outlines the marble and rice' model as a teaching tool to help learners comprehend metallic bonding and its properties while improving engagement in chemistry lessons at the senior school level.

The Teaching Challenge

While teaching metallic bonding, I noticed that my learners struggled to grasp the concept despite prior instruction. Their classroom responses and performance in exercises indicated that they were not fully grasping the concept. Several misconceptions were persistent: many learners viewed metals as neutral atoms rather than positive ions, some confused metallic bonding with ionic bonding or incorrectly assumed that electrons remained in fixed positions rather than being delocalized. In addition, learners showed low engagement during the lesson, especially when abstract explanations were used. This prompted me to reflect on my teaching approach and I explored an alternative teaching strategy that uses everyday materials to make invisible chemical processes visible.

The Instructional Innovation: Marble and Rice Model

To address this challenge, I developed a simple model using:

Glass marbles to represent positively charged metal ions

Rice grains to represent delocalized electrons

A shallow tray to hold the arrangement

In this model:

The marbles are arranged closely together to represent a metallic lattice

The rice grains are placed between the marbles to represent the "sea" of electrons

This setup allowed learners to visualize the structure and simulate the movement of electrons within the metallic bond.

Implementation of the Strategy

To enable learners understand the abstract concept on metallic bonding, I designed a lesson centered on physical modeling:

I began with a brief review of atomic structure and types of bonding.

Learners were introduced to the concept of metallic bonding through guided discussion.

Learners were grouped into small groups of five.

Each group was provided with marbles, rice grains, and a tray.

Learners arranged the marbles in a closely packed structure to represent metal ions.

Rice grains were added between the marbles to represent delocalized electrons.

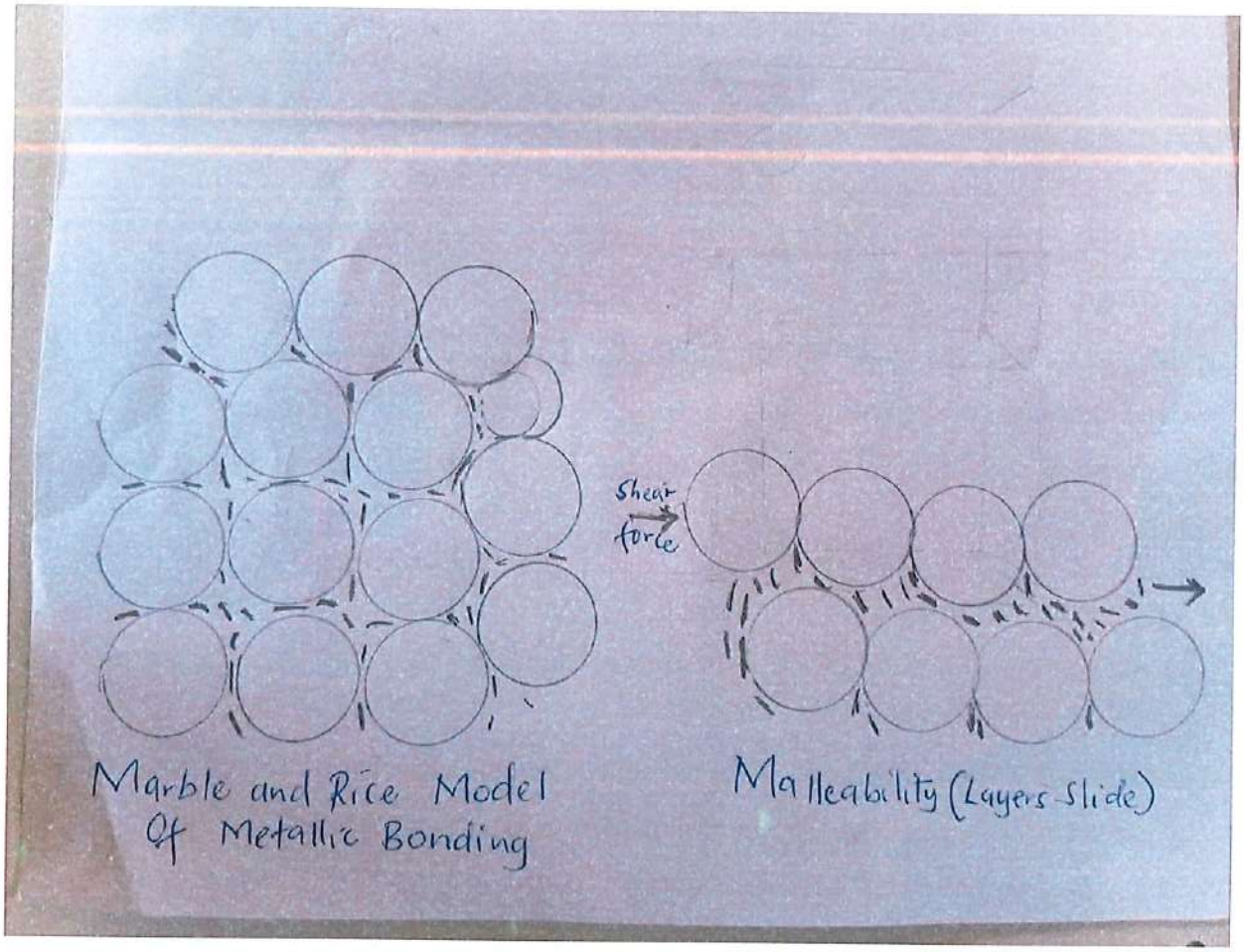
Learners gently tilted the tray and observed how the marbles moved while maintaining the structure. This observation was used to explain:

Malleability (layers sliding over each other)

Ductility

Electrical and thermal conductivity

A class discussion and exercise followed, linking the model to real-life applications of metals.



Observed Changes in Learners

The use of the marble and rice model led to noticeable improvements in both learner engagement and understanding

Improved Conceptual Understanding

Learners were able to:

Correctly describe the arrangement of metal ions in a lattice

Explain the role of delocalized electrons

Relate electron movement to conductivity

Explain malleability and ductility using the model

Increased Learner Engagement

They actively participated in group activities

There was increased discussion and peer explanation

They showed curiosity through asking more questions

Improved Performance

Comparison of learner performance before and after the lesson showed improvement. For example:

Many learners who initially struggled to explain metallic bonding were able to give clear explanations after the activity

Follow-up assessment scores improved, showing better conceptual understanding

Learners' responses

Table 1 below shows responses of each group and their mean scores before and after use of the model

Table 1

Learners Responses

Group Number	Before use of model	After use of the model
1	59	82
2	35	78
3	45	44
4	20	70
5	65	78
6	44	44
7	64	80
8	70	78
Mean %	**50.25**	**69.00**

Ethical considerations

To ensure participants confidentiality, the identities of the individual learners and group members were kept strictly anonymous. Additionally the exercise was designed to ensure inclusive participation among all learners. The material used (marble and rice) guaranteed safety to learners.

Reflection on Practice

The responses before use of the model showed a mean score of 50.25% while after use of the model the mean score was 69.00%. This (18.75%) increase demonstrates that the marble and rice model is an effective strategy for addressing learners' misconceptions and making abstract concepts more concrete. Furthermore, the hands-on nature of the activity allowed learners to actively construct their own understanding rather than passively receive information. The strength of the model is the use of locally available and low-cost materials, making it accessible to teachers in different contexts. The model also promotes collaborative learning, communication, and problem-solving skills, which are core competencies in the CBE framework.

However, I noted that the effectiveness of the model depends on proper guidance. Without clear explanation, learners may misinterpret the representation. In future lessons, I would provide more structured guiding questions to further deepen understanding.

Conclusion

The marble and rice model is a simple, affordable, and effective teaching strategy for improving learners' understanding of metallic bonding. By transforming an abstract concept into a tangible experience, the model enhances learner engagement and supports meaningful learning. Teachers are encouraged to adopt similar hands-on approaches to improve the teaching and learning of complex scientific concepts.

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Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA)

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