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Assessing the Ability of Physics Teachers to Design Investigative Experiments for the Acquisition of Science Process Skills among Physics Learners in Secondary Schools in Tharaka Nithi County-Kenya

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Abstract:- Teaching science is demanding for teachers as they are required to develop a conceptual understanding of the practical tasks and scientific inquiry. To implement an investigative approach the teachers, need to have a sound understanding of the investigative process. Science investigative is a mode of teaching that involves practical work to provide students with opportunities to employ concepts cognitive processes and problem-solving skills. Despite the plans and interventions developed by the government through the Ministry of Education, there are challenges with teachers' abilities to implement investigative experiments. This study sought to assess teachers' abilities to design investigative experiments to enhance the acquisition of science process skills among learners in Tharaka-Nithi County. The study sampled 24 teachers from a targeted population of 236 teachers from 4 sub-county public secondary schools selected purposively. A research questionnaire and a checklist were used to collect data which was analyzed using SPSS. The findings of the study showed that teachers reported moderate competencies in designing and conducting investigative activities. It was evident that teachers employed low-inquiry levels indicating a gap in their implementation of the investigative experiments for effective acquisition of science process skills by learners. The study recommended that education stakeholders invest in enhancing teachers' competence in the science investigation process.

Keywords:- *Science Process Skills, Investigative Experiments, Designing Experiments, Teachers' Abilities.*

I. INTRODUCTION

➢ *Background Information*

The global advancement in technologies has spurred research and investment in science subjects to encourage technological innovation. The role of Physics in the fields of Science, Technology, Engineering, and Mathematics (STEM) cannot be ignored. The knowledge and skills attained in Physics are vital in operating technological tools necessary in areas such as; communication, agriculture, schools, manufacturing, and hospitals (Mollel et al., 2022). For instance, the development of new products such as computers, nuclear weapons, domestic appliances, phones, and television which are transforming modern-day society is a result of understanding electromagnetism and nuclear physics (Holubova, 2024). Physics enables students to gain cognitive skills that help them confront real-world problems and invent reasonable solutions.

The Kenyan government in 1984 underscored the importance of physics in preparing learners for vocations and careers at tertiary levels of education making the subject compulsory in the first two years of secondary education (Murei, 2016). Further, Physics is a major catalyst in the realization of Vision 2030 with Kenya anticipating to become an industrialized country by the year 2030 (Ministry of Education, Science and Technology, 2007). Learning physics requires students to obtain science process skills which are critical in solving everyday problems.

Science process skills (SPS) are critical in performing science research and problem-solving. The skills are categorized into either basic scientific process skills or integrated process skills (Shakibu & Agyei, 2023). The basic scientific skills include inferring, observing, measuring, communicating, classifying, and predicting. The integrated SPS includes variable identification, hypothesis construction, tabulation and data graphing, variable definition, designing interventions, and experimentation (Subali et al., 2016). The science process skills both basic and integrated are fundamental to understanding of science subjects, specifically Physics and teachers should have transferable abilities to help students acquire these skills.

A study by Gizaw & Sota (2023) to assess strategies to improve the practices of science process skills of students through a review of the literature indicated that teaching strategies particularly student-centered methods and multiple

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representation approaches enhanced students' SPS. According to the study, teachers are critical in organizing the teaching environment, designing the teaching methods and activities, facilitating the teaching-learning in a classroom, and helping students to develop SPS. Therefore, for effective acquisition of SPS among learners, teachers are supposed to have a strong conceptual understanding and the ability to perform SPS. However, there is evidence from research that most teachers lack the competence and ability to facilitate learners' acquisition of the SPS.

KaramustafaoÄŸlu (2011) study using a basic experimental design to identify the level of science and technology student teachers' science process skills among 40 teachers from Amasya University showed that the teachers had challenges with pre-tests, especially with the integrated process skills. The study revealed that most teachers were struggling with hypothesizing, identifying, and controlling variables, and data interpretation. A similar study by Aydogdu (2015) employed a survey design to investigate SPS skills among 170 science teachers in Central Anatolia Region of Turkey and found that teachers' science process skills did not reach a satisfactory level to enable them to teach students effectively. The teachers' basic process skills scored 48% while their integrated process skills were at 44%.

According to a study by Nderitu & Elimlim (2023) to examine the problems affecting the teaching and learning of Physics in selected schools in Turkana County, Kenya, the availability of teaching and learning materials, learners' and teachers' attitudes towards the use of experiments and discussions and teachers' competence in delivering investigative instruction were critical challenges. Another study to establish students' learning challenges in studying Physics in public secondary schools in Laikipia East Sub-County, Kenya showed that the teaching methods of physics and teacher characteristics were a major challenge (Ndegwa, 2018). The study revealed that most teachers in the sub-county did not use learner-centered methods of teaching such as field work, instruction, constructivism, and discussion. Evidence from the study indicated that these teachers lacked confidence in using these methods and using student-centered activities as advocated by SMASSE.

Kenya has put numerous efforts to build science teachers' capacity to teach science subjects. For instance, through the Centre for Mathematics, Science, and Technology Education in Africa (CEMASTEA) there has been continuous teacher professional development for science and mathematics teachers to enhance their pedagogical skills (Orado et al., 2023). CEMASTEA runs a Secondary Education Quality Improvement Project (SEQIP) that operates a School Based Teacher Support System (SBTSS) for Science, Mathematics, and English (SME) teachers in both primary and secondary schools to improve their pedagogical and content knowledge. Despite these efforts, teachers' ability to design investigative practical tasks for students in Physics remains limited. This study sought to establish the ability of physics teachers to design investigative practical tasks for the acquisition of SPS.

- *Statement of the Problem*

Science process skills are critical in cultivating students' problem-solving abilities including logical thinking and questioning. Teachers have a central role in nurturing these skills among learners. Schools with well-equipped teachers who can design appropriate investigations effective in imparting SPS among learners. Successful designing of investigative experiments requires teachers to have professional development in planning and executing experiments. Training teachers to design experiments that engage learners in problem-solving and critical thinking while adhering to the learning objectives in the curriculum is fundamental. There should be regular professional development workshops and coaching to improve teachers' experimental design, data analysis, and regular coaching, and ultimately enhance students' acquisition of SPS. Research in Kenyan secondary schools indicate that human resources trained in designing investigative experiments are limited. Most teachers in these schools though aware of the importance of investigative experiments in enhancing learners' SPS, lack the ability to effectively implement the experiments. This study sought to assess the ability of physics teachers to design laboratory Investigative tasks for acquiring science process skills among physics learners in Tharaka Nithi County.

- *Objectives of the Study*

This study sought to assess the ability of physics teachers to design Investigative Experiments for the acquisition of science process skills among physics learners in Tharaka-Nithi County.

- *Research Question*

What are the physics teachers' abilities in designing investigative experiments for the acquisition of science process skills among physics learners in Tharaka-Nithi County?

II. METHODOLOGY

This study employed a mixed-method research design to assess teachers' competencies in designing investigative experiments for enhancing learners' acquisition of science process skills. This type of research design is most suitable when a researcher is required to integrate findings and draw inferences using both qualitative and quantitative approaches in a single study (Doyle et al., 2009).

This study targeted 236 teachers from 135 public secondary schools in Tharaka Nithi County. Purposive sampling was used to select 24 physics teachers which is 10.17% of the targeted teachers. According to Chen et al., (2019), a sample of 10-30% of the target population is adequate in research. Purposive sampling was considered suitable for this study because it helped select the most relevant teachers who were Form Two teachers teaching the Hooke's Law topic.

The study used several research instruments to collect data on teachers' abilities in designing investigative experiments. A questionnaire was used to assess the teachers'

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ability to construct investigative tasks using a 5-point Likert Scale. A lesson observation guide was employed to investigate physics teachers' capabilities in designing the investigative experiment tasks during the practical lessons. The researcher observed teachers as they facilitated the learners on how to devise experiments, work independently, solve practical problems, and analyze and interpret data obtained from the experiments. The guide was suitable because it provided more information for analysis that complements data from other research instruments (Roulston et al., 2018). Three practical lessons were observed and scored at their inquiry level. The scoring involved a rubric that was designed to measure the frequency and quality of the inquiry in the lessons. A checklist was used to list teachers' actions during the practical investigative lesson and tabulate the observations. The researcher also used a checklist to tabulate teachers' levels of engaging learners during the investigative experiments. A pilot study was conducted in one sub-county public secondary school selected purposively and among three physics teachers to assess the reliability and validity of the research instruments.

Data was cleaned and analyzed using the Statistical Package for Social Sciences (SPSS). The study used descriptive statistics in the form of percentages and presented the results in Tables. Permission from the County Director of Education, Tharaka-Nithi County was sought to undertake the research in public schools. Secondary school principals in the sampled schools were consulted to allow the study to be carried out in their schools and the researcher booked appointments with the physics teachers. Teachers were well informed of the study purpose and confidentiality and privacy were assured to them before they filled an informed consent. Data collected was anonymous to promote participant confidentiality.

III. RESULTS AND DISCUSSION

This section presents results on physics teachers' abilities in designing investigative experiments to enhance the acquisition of science process skills among learners in Tharaka-Nithi County.

- *The Ability of Physics Teachers to Design Laboratory Investigative Tasks for Acquiring Science Process Skills among Physics Learners*

The study sought to investigate the abilities of teachers in different activities that involve designing laboratory investigative tasks to help students develop science process skills. Some of the abilities considered in this study were competencies in; selecting an investigative instructional approach, question formulation, designing experiments and investigations, preparing class debates and discussions, designing individual and group projects, preparing class assignments, and organizing and preparing instructional materials. Table 1 presents the teachers' abilities in selecting investigative approaches, question formulation, and preparing instructional materials.

Table 1 Teachers' Competencies in Selecting Investigative Approaches, Question Formulation, and Preparing Instructional Materials

Competencies	Average (3)	Moderate (4)	High (5)
Selecting an investigative practical instructional approach			
Selection of a suitable inquiry instructional method	0(0%)	16(80.0%)	4(20.0%)
Design and Devise Strategies	8(40.0%)	8(40.0%)	4(20.0%)
Learning facilitation using a range of methods and strategies	7(35%)	12(60.0%)	1(5%)
Question Formulation			
Looking into and challenging student thinking and reasoning	4(20.0%)	12(60.5%)	4 (20.0%)
Instigating the evaluation and communication of strategies	11(55.0%)	8(40.0%)	1(5.0%)
Uncovering misconceptions	7(35.0%)	11(55.0%)	2(10.0%)
Supporting students to learn from mistakes	1(5.0%)	15(75.0%)	4(20.0%)
Provoking and stimulating the exploration of alternative routes	11(55.0%)	8(40.0%)	1(5.0%)
Organizing and preparing instruction materials			
Schemes of work preparation Lesson plan	1(5.0%)	1(5.0%)	18(90%)
Records of work	1(5.0%)	1(5.0%)	18(90%)
Level of syllabus coverage and student progress records	0(0.0%)	4(20.0%)	16(80.0%)

The majority of the teachers (80%) had moderate competence in selecting an investigative practical instructional approach. Only 20% of these teachers registered high competency in designing and devising strategies for instructional purposes. Further slightly above half of the teachers (60%) reported moderate competence levels in learning facilitation using a wide range of strategies and methods. About 40% of the teachers had high levels of competency in promoting learners' thinking and reasoning through the formulation of questions in investigative experiments. Approximately half of these teachers (55%) reported average competency in instigating the evaluation and communication strategies involved in question formulation. Most teachers (75%) reported moderate competence in supporting students to learn from mistakes. The study indicated average competence in provoking and stimulating the exploration of alternative routes among 55% of the sampled teachers. Teachers reported high competence in preparing and organizing schemes of work preparation lesson plans (90%), records of work (90%), and level of syllabus coverage and student progress report (80%). Competency in organization and preparation among teachers helps in optimizing student learning and contributes to their development and success (Québec, 2021).

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Science investigation supports students' learning through the discovery of new knowledge, integration, and practical work. Teacher's competence in experiment designing and investigation promotes SPS among students and makes learning science subjects interesting for students (Wang et al., 2018). Table 2 results present the levels of teachers' competence in planning and implementing investigative experiments for the physics learners.

Table 2 Teachers' Competency in Designing Experiments and Investigations, Individual and Group Projects, and Class Assignments

Competencies	**Average(3)**	**Moderate(4)**	**High(5)**
Designing experiments and investigations			
Gain practical research skills and master research methods	9(45%)	10(50%)	1(5%)
Learn how to work safely with the physical equipment	0(0%)	8(40.0%)	12(60.0%)
To collect, process, and convey the results of the experiment and link them to theoretical models	4(20.0%)	11(55%)	5(25%)
To make generalizations and conclusions	4(20.0%)	7(35%)	9(45%)
Designing class debates and discussions through the provision of collaborative learning opportunities.	3(15%)	13(65%)	4(20%)
Designing individual and group projects			
Organize collaborative activities	9(45%)	9(45%)	2(10%)
Merge small-group activities for students to share ideas, develop Physics arguments, and challenge views	0(0%)	15(75%)	5(25%)
Fostering and managing collaborative work	7(35%)	13(65%)	0(0%)
Creates 'conditions and means' for collaboration	6(30%)	13(65%)	1(5%)
Identifies areas for revision	2(10%)	11(55%)	7(35%)
Reflects on the entire process	0(0%)	13(65%)	7(35%)
Designing class assignments among teachers			
Involving students in self and peer-assessment	4(20.0%)	13(65%)	3(15%)
Designing assessment activities or writing assignments that include a ''transfer of learning'' prompt	7(35%)	12(60.0%)	1(5%)
Tailoring assignments, and activities to address misconceptions and scaffold student learning	8(40.0%)	11(55%)	1(5%)
Tailoring assignments, and activities to address misconceptions and scaffold student learning	8(40.0%)	11(55%)	1(5%)

A slightly equal proportion of the sampled teachers reported average (45%) and moderate (50%) competency in practical research skills and research methods used in designing investigative experiments for the acquisition of SPS. More than half of the teachers (60%) could observe safety when working with physical equipment in investigative experiments. Slightly above half (55%) of the teachers showed moderate competence in collecting, processing, and conveying experiment results and promoting linkage with theoretical models. A study by Dudu & Vhurumuku (2012) supported the findings of this study on designing and conducting investigative experiments by indicating that teachers' practices are fundamental in supporting students in scientific inquiry practices which include data collection, designing and conducting investigations, and framing research questions. Additionally, 45% of the teachers had high competency in generalizing and conclusions concerning experimental designs. More than half of the teachers (65%) had a moderate level of competence in designing class debates and discussions through collaborative learning opportunities.

Only a small proportion of sampled teachers (10%) were proficient in organizing collaborative activities. Only a quarter (25%) of the teachers had high proficiency in merging small-group activities for students to share ideas and develop Physics arguments. A study by Moeed (2013) indicates that there are few studies indicating examples of successful implementation of science investigation with most research showing gaps in the implementation process. The results do not agree with Zabala & Dayaganon (2023) study which showed that teachers' competency in designing investigative tasks in Chemistry was high. However, 65% of teachers had moderate competency in fostering and managing collaborative work to enhance group projects. Similarly, the same proportion had a moderate level of competence in creating "conditions and means" for collaboration. An equal proportion of teachers (35%) slightly above a quarter of the sampled number reported high proficiency in identifying revision areas and reflecting on the entire process.

Teachers experienced difficulties in designing class assignments as those with high competence levels were below a quarter of the sampled teachers. For instance, only 15% of the teachers were highly competent in students' involvement in self and peer assessment. Only 5% of teachers had a high level of competency in tailoring assignments, whose activities are meant to address misconceptions and also to scaffold student learning to improve students' ability to acquire science process skills.

Investigative laboratory instruction helps learners engage in practical-based activities that promote their development of SPS. Learners' engagement in investigative

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experiments is categorized into four different levels of inquiry. Results in Table 4 reveal the teachers' common inquiry levels adopted in physics investigative experiments. The level of inquiry was decided upon based on questions, procedures, and solutions being either open to the student or given.

Table 3 The level of Information Provided in the Engagement of Learners during Physics Investigative Experiments

		Solution	**Given**	**Open**
Question	Procedure			
Given	Given		5(level1)	12(level2)
	Open		0	3(level3)

Most of the teachers (12) used a structured inquiry approach where learners are required to investigate a teacher-presented question using a prescribed procedure. Only five teachers adopted a confirmation inquiry method that requires students to confirm a given principle through a specified activity with known results. The remaining teachers relied on a guided theory model where teachers provide students with questions and later design procedures to offer solutions. The study findings on the inquiry level indicate a gap in the teachers' ability to implement investigative experiments. According to Gholam (2019) extensive practice is needed for learners to conduct investigative experiments independently and achieve the highest level of inquiry-based learning.

IV. CONCLUSION

The majority of the teachers reported moderate levels of competence in selecting investigative instructional approaches, formulating questions that challenge learners' intellectual capacity to enhance their critical and analytical thinking skills. Though most of the teachers were comfortable designing experiments and had an understanding of the practical procedures, there were gaps in their designing of individual and group projects and class assignments. However, teachers' competency in organizing and preparing investigative tasks was fairly good. There were gaps in designing class debates and discussions to promote collaborative learning opportunities. The study findings reveal that teachers had inadequate abilities in achieving the highest level of inquiry-based learning as most of them demonstrated a lower level of inquiry. A low level of inquiry results in gaps in implementing investigative-based learning in Physics. The study recommends training of teachers as key stakeholders in the implementation process to equip them with the needed skills to enhance acquisition of science process skills among learners.

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