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Implementation of Constructionist Learning Objectives in the Physics Syllabus for Tanzanian Ordinary Secondary Education

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Abstract
This study investigated the context in which physics constructionist learning objectives are implemented in Tanzanian Ordinary secondary schools as per physics syllabus. Educational design research (EDR) methodology was employed. The study examined the number of physics constructionist learning objectives (CLOs) in the syllabus, the implementation status of these CLOs in schools, and the implementation challenges of CLOs. A total of 206 respondents, including 192 Form IV students, 12 physics teachers and 2 physics curriculum development coordinators participated in the study. Data were collected using documentary review, focus group discussion, questionnaire and interview. Data analysis was carried out quantitatively and qualitatively. The study revealed that there are 20 CLOs in the 2007 physics syllabus for Ordinary Secondary Education. Findings showed that most secondary schools did not implement constructionist learning objectives as per the syllabus due to multiple challenges faced. The study concludes that there is a mismatch between curriculum intentions and the implementation practice in schools. Based on these findings, it is highly recommended that the multiple challenges hampering the implementation of physics CLOs in schools be addressed by the government and other responsible authorities. It is also recommended that a study be conducted to investigate key characteristic components of the constructionist learning environment for enabling and enhancing the implementation of physics CLOs in Tanzanian secondary schools.

Keywords: *Constructionism, constructionist learning objectives, physics, ordinary secondary education*

Introduction

Constructionist Teaching and Learning in Schools

Tanzania's Ordinary secondary education physics syllabus requires constructionist (constructivist) teaching and learning approaches as some specific objectives in the syllabus require students to construct knowledge and some artefacts. According to MoEVT (2007), the physics syllabus outlines one among the specific objectives that "the student should be able to construct a simple hydrometer" (p.9). Specific objectives that require students to construct tangible and sharable artefacts in the process and as an outcome of learning are called Constructionist Learning Objectives (CLOs). The implementation of CLOs is guided by the constructionism learning theory as espoused by Seymour Papert (Papert & Harel, 1991). Also, the Revised Bloom's Taxonomy (Anderson & Krathwohl, 2001) indicates that 'creating', the highest cognitive skill, can be effectively developed among students with stipulated CLOs in the learning syllabus.

Constructionist Learning Theory

Constructionist learning theory believes that building knowledge occurs best through building things that are tangible and sharable (Ackerman et al., 2009). Constructionism in the context of learning is the idea that people learn effectively by making tangible and sharable artefacts as objects to think with (Papert & Harel, 1991). Papert (1993) maintains that constructionism is both a theory of learning and a strategy for education which builds on the constructivist theories of Jean Piaget, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed in the mind of the learner. In practice, constructionism in the form of physics CLOs can be implemented through projects-oriented learning (Kyomo, 2010), Learning by Design (LBD) and Project Based Learning (PBL) approaches (Han & Bhattacharya, 2001; Sharif & San, 2001) in the constructionist learning environment. Benefits of constructionist teaching and learning approaches include making physics popular to many students; constructing devices that can be used as physics teaching aids for own school use, and enhancing students' achievements in physics tests and examinations (Kyomo, 2018, 2010). They also include improving students' confidence in studying physics, localising physics to the surroundings of the students, and developing creativity, critical thinking skills and innovative abilities in students (Kyomo, 2018; 2010; 2006; 2004). Other benefits of constructionist teaching and learning are that learners construct meaning and internalise the learning process; learners increase their motivation to learn, improve their research skills, increase collaboration skills, and increase resource management skills (Han & Bhattacharya, 2001; Ravitz & Mergendoller, 2005; Mergendoller et al., 2006; Belland et al., 2006; Brush & Saye, 2008).

Students' interest is increased in the subject due to participation in learning through PBL, which increases students' collaboration skills (ChanLin, 2008). Some challenges related to constructionist teaching and learning approaches such as project-oriented learning, project-based learning and learning by design have been identified to include a lack of time management skills and organization skills among teachers and students and teachers' low competence to facilitate students' learning through this approach (Brush & Saye, 2008; Kyomo, 2018, 2010). Several studies have been conducted on science teaching and learning in Tanzania with regard to the teaching and learning environment and its effect on students' preferences and performance in science subjects (Mabula, 2012; Ndalichako & Komba, 2014; Kihwele, 2014; King'aru, 2014; Kibga, 2004). Some studies have reported on teachers' low competence in teaching science subjects with activity-based practical works (Mwakalinga, 2015; Kyomo, 2018, 2010; Kira & Nchunga, 2016; Kibga, 2004, Kyomo, 2004). Researchers criticise the teacher–centred teaching methods which deny students' activities such as project and practical works in learning physics (William, 2008; Tilya, 2003; Richard, 2005; McLoughlin & Taji, 2006; Mwinyi, 2008; Muna, 2008). Also, some studies have covered on students' attitudes and perceptions toward learning physics (Mollel et al., 2022; Kwarikunda et al., 2020; Mbonyirivuze et al., 2021; Tadele & Sitotaw, 2016; Ndunguru et al., 2013).

Despite many educational benefits from constructionist teaching and learning, the approaches have been rarely or not employed due to several challenges. Few studies have been done in the Tanzanian context to study the implementation of physics CLOs as required in the syllabus. Also, in spite of the emphasis by MOEVT (2007, 2017) on using constructionist learning approaches, activity-based, practical, problem-solving, learner-centred, participatory teaching methods for secondary school physics, still, these methods are rarely used (Kyomo, 2018; Mwakalinga, 2015; Lutege, 2008; Kyomo, 2010). Several studies have revealed some major reasons for this situation being lack of teaching and learning equipment and materials; and lack of practical competence for teachers to use these methods. Many studies in Tanzania have covered generally on science teaching methods and investigated little on the contextual implementation of physics CLOs in Tanzanian secondary schools.

The Current Study

This study intended to do the following: (a) to examine constructionist learning objectives in the physics syllabus; (b) to assess the implementation status of physics constructionist learning objectives in secondary schools; (c) to investigate the implementation challenges of physics constructionist learning objectives in secondary schools.

Methodology

The study was carried out in Morogoro Municipality in Morogoro region, in which six secondary schools were randomly sampled. The sample included three public and three private secondary schools. Educational design research (EDR) (McKenney & Reeves, 2012) methodology was employed. The first phase-context analysis related to the implementation of physics constructionist learning objectives and its associated aspects was carried out. The study sample included 192 Form IV students who were randomly selected from six secondary schools, 12 physics teachers and 2 physics curriculum development coordinators, all making a total of 206 respondents. Four data collection methods were employed, including a documentary review of related documents, focus group discussion with physics teachers and students, a questionnaire for form IV students, and an interview with physics curriculum development coordinators. Data from student questionnaires were analysed quantitatively using frequencies and percentages, whereas qualitative data generated from interviews, focus group discussions and documentary reviews were coded and analysed using content analysis.

Results and Discussion

Constructionist Learning Objectives in Physics Syllabus

A documentary review of the 2007 (third reprint, 2017) physics syllabus revealed a total of 467 specific learning objectives, of which 96 were in Form I, 120 for Form II, 148 for Form III and 103 for Form IV. The 2007 physics syllabus was reprinted in 2010, 2012, and 2017 and is still in use in 2024. It has been revealed further that there are 20 CLOs out of 467 specific learning objectives, which is about 4 per cent (4%) as indicated in Table 1.

Table 1: Constructionist Learning Objectives in the 2007 Physics Syllabus

S/N	Constructionist Learning Objectives (CLOs) The student should be able to:	Form	Sub-topic Number
1.	(g) Construct a simple hydrometer	I	5.2
2.	(c) Describe the construction of an air-filled capacitor	II	1.4
3.	(c) Construct a simple lighting conductor	II	1.6
4.	(c) Design methods of storing magnets	II	3.2
5.	(c) Construct a model of hydroelectric power plant	II	9.1
6.	(c) Construct a model of solar panel	II	9.2
7.	(c) Construct a model of wind mill	II	9.3
8.	(b)Construct a model of changing sea wave to electricity	II	9.4
9.	(d) Construct a simple prism binocular	III	4.0
10.	(c) Construct a simple microscope	III	4.1
11.	(e) Construct a simple compound microscope	III	4.2
12.	(e) Construct a simple astronomical telescope	III	4.3
13.	(e) Construct a simple projected lantern	III	4.4
14.	(c) Construct a simple lens camera	III	4.5
15.	(c) Perform wiring on Board	III	9.4
16.	(h) Construct a simple musical instrument	IV	1.5
17.	(f) Construct a simple step up and step-down transformer	IV	2.2
18.	(d) Construct a half-wave rectifier	IV	5.2
19	(d) Construct a full-wave rectifier	IV	5.2
20.	(c) Design a single stage amplifier	IV	5.4

Source: Documentary Review of 2007 Physics syllabus, (2017)

Table 1 indicates that one CLO is proposed in the physics syllabus for Form I, seven (7) CLOs for Form II, seven (7) CLOs for Form III, and five (5) CLOs for Form IV. The presence of CLOs in the 2007 Physics syllabus shows emphasis on the use of constructionist (constructivist) teaching and learning approaches through which students construct both knowledge and artefacts that are tangible and sharable in the real world (Papert & Harel, 1991). In implementing these CLOs, students are developing 'creating' skills as stipulated in the Revised Bloom's Taxonomy (Anderson & Krathwohl, 2001). Generally, analysis shows that the implementation of physics CLOs, as outlined in the syllabus, has a high potential of creating opportunities for students to develop higher-order thinking (HOT) skills necessary for them to live competitively in the 21st century. Anderson and Krathwohl (2001) argue that HOT skills can be approached as the three top-end levels of Bloom's (or any other) taxonomy: analysing, evaluating and creating. Also, Brookhart (2010) identifies three categories of definitions of HOT skills to be in the transfer (application) of knowledge, critical thinking and problem-solving. The HOT, in terms of transfer of learning, requires that students not only remember but also make sense of and be able to use (apply) what they have been taught (Anderson & Krathwohl, 2001). Transfer of learning makes one of the two most important educational goals of retention and transfer. Transfer of learning by students to various contexts leads to meaningful learning.

Implementation Status of Physics CLOs in Secondary Schools

Information on the implementation status of physics CLOs in physics teaching and learning was sought from physics teachers through FGD and form IV students through FGD and questionnaires. Other information was collected from physics Curriculum Development Coordinators (at the Tanzania Institute of Education, TIE) through interviews and documentary reviews of physics schemes of work, lesson plans, and lesson notes from participating schools. The implementation status of physics CLOs was rated at five levels depending on how physics teachers in these six schools implemented 20 physics CLOs as proposed in the 2007 physics syllabus. Form IV students were to implement these CLOs in 2017 for the past four years since 2014 using the rating scale indicated in Table 2. The teachers' responses through focus group discussion were as follows: Only one school out of six (17%) responded to having implemented only one physics CLO (low extent in physics teaching and learning). Five out of six (83%) schools had no extent of implementing physics CLOs for the 2017 Form IV students' cohort. The findings are similar to those reported by Kyomo (2010), who reported that schools rarely implemented physics CLOs or did not implement them at all. Through questionnaire, students gave useful information on the extent of implementation of physics CLOs.

The extent of implementation of physics CLOs was observed in the student's participation in learning through such CLOs. Students were required to show if they participated in learning physics through CLOs during their four-year period (2014-2017) of their ordinary level ordinary-level secondary education. Table 2 presents the responses from students' questionnaires on the implementation status of physics CLOs in secondary schools. Table 2 indicates that 24 out of 144 students (17%) said YES; they participated in learning physics through only one CLO when they constructed a hydrometer when they were in Form I in 2014. 120 out of 144 students (83%) who responded to the questionnaires said NO, they did not participate in learning physics through any physics

CLOs during their four-year period (2014-2017) of ordinary secondary education.

Table 2: Implemented status of physics CLOs from Form IV students' Questionnaire

SN	Response	Rating description	Number	%
1	No	No extent of implemented physics CLOs (0 CLOs implemented by 2017 Form IV cohort of students)	120	83
2	Yes	Low extent of implemented physics CLOs (1-5 CLOs implemented by 2017 Form IV cohort of students)	24	17
3	Yes	Moderate extent of implemented physics CLOs (6-10 CLOs implemented by 2017 Form IV cohort of students)	0	0
4	Yes	Good extent of implemented physics CLOs (11-15 CLOs implemented by 2017 Form IV cohort of students)	0	0
5	Yes	Great extent of implemented physics CLOs (16-20 CLOs implemented by 2017 Form IV cohort of students)	0	0
		Total	144	100

Source: Field data, (2017), Morogoro Municipality

Table 2 indicates that, overall, the implementation of physics CLOs in secondary schools is very low. Even for students who participated, they implemented only one out of twenty (5% only) physics CLOs proposed in the syllabus. These students' low participation in implementing CLOs denies them opportunities to develop higher-order thinking skills such as problem-solving, critical, and creative thinking. These findings are related to the dominant teaching methods, as some studies indicated that most of the teachers used lecture methods in teaching science subjects in secondary schools, and schools lacked laboratories (Mwakalinga, 2015; Mwinyi, 2008; Kyomo, 2010).

Implementation Challenges of Physics CLOs in Secondary Schools

The information on the challenges facing the implementation of physics CLOs in secondary schools was obtained from physics teachers' FGD and Form IV students' focus group discussions and questionnaires. They identified challenges facing the implementation of physics CLOs to include teachers' low competence in facilitating CLOs in secondary schools, lack of construction (working) tools, lack of construction materials, and lack of working space/place at schools for construction activities. Other challenges included lack of storage space/place for construction activities at school; inadequate textbooks/reference books and electronic resources (e-resources), lack of time to carry out CLOs at school within classroom timetable, and lack of funds to support other related tasks.

Furthermore, there is a lack of assessment guidelines for students' learning products (artefact and construction report) from implemented CLOs, a lack of qualified physics teachers in some secondary schools, and a lack of motivation to engage in supporting CLOs in secondary schools. More challenges included a lack of support from school leadership and management and a lack of safety gear for implementing physics CLOs. Last but not least, there is a lack of environmental protection gears for implementing physics CLOs and a lack of books or information resources to guide students on what and how to construct devices as means for active physics learning. These findings are similar to the findings from other studies which reported multiple constraints facing schools in science teaching through activity-based learning, participatory, and hands-on and minds-on approaches like practical works and projects (Kyomo, 2018; King'aru, 2014; Mwakalinga, 2015; Kyomo, 2010; Mwinyi, 2008). Implementation of physics CLOs belongs to the practical activity-based learning and problem-solving teaching and learning methods. GTZ (2000) reported that the quality of instruction in the teachers' colleges is poor as they are taught predominantly through lecture methods. In some cases, pre-service teacher training does not provide models or skills for effective teaching methodology (Lutege, 2008; Mwinyi, 2008).

Conclusion and Recommendations

Based on these findings, it can be concluded that there is a reasonable number of constructionists learning objectives (4 per cent of the total) among specific learning objectives stipulated in the physics syllabus. However, they are implemented to a low extent due to multiple challenges that require various inputs. On the basis of these findings, it is highly recommended that the multiple challenges hampering the implementation of physics constructionist learning objectives in schools should be addressed by the government and other responsible authorities. It is also recommended that a study be conducted to investigate key components of the constructionist learning environment for enabling the implementation of physics constructionist learning objectives in Tanzanian secondary schools.

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