EFFECTS OF CONCEPT MAPPING BASED INSTRUCTION ON STUDENTS' ACHIEVEMENT IN PHYSICS IN SECONDARY SCHOOLS, KENYA

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Candidates' responses to a large extent show partial concept development (KNEC, 2006). The purpose of this quasi-experimental study using pre-test and post-test with control and experimental groups was to determine if combining instructional concept mapping (ICM) and conventional instructional techniques (CIT) would improve students' achievement in physics. Validated instruments were used to gather data on students learning achievements in physics, role of physics teacher and student, and challenges encountered in ICM and CIT lessons. Analysis of data was done using both descriptive and inferential statistics. It was found that students in the concept mapping group were more participative in class and obtained a statistically significant higher mean gain on the physics test compared to the non-concept mapping class, with $p < 0.05$. It was concluded that generating instructional concept maps is an effective teaching and learning tool for developing physics concepts.

Keywords: Instructional concept mapping, Conventional, Improve, Achievement

Introduction

Kenya's economy requires a steady supply of scientifically and technologically knowledgeable human resource (Mutahi, 2009). This underscores the fact that science and technology have immense contribution to the growth and development of a country. Consequently, students should be equipped with the necessary knowledge and skills in science and technology to function in modern times.

Any breakthrough in science and technology is deeply rooted in the strength of science education. It is in recognition of this dominant position occupied by science that during the Fifth Ordinary Session of the Conference of Ministers of Education in Africa (COMEDAF V) held in April 2012 in Abuja, Nigeria, Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA) was showcased as model 'Centre of Excellence' in the promotion of quality of mathematics and science education at the basic level in Africa (Mutula, 2012).

Physics is one of the science subjects taught under science education. Advancements in technologies in information and communication, medical, environmental, crime control and security, among others, are some of the achievements brought about by physics. Therefore, specific priority of physics in the development of scientific and technological programmes of a nation is important.

In Kenya, the experience of low enrolment and poor performance in physics among students at varying levels of learning is reflected in the candidates' performance in the Kenya Certificate of Secondary Education (KCSE) Physics examination between the years 2006 and 2010 as shown in Table 1.

Table 1: Candidates' Overall Performance in Physics in the Years 2006 to 2010

Year	Candidature	Percentage Candidature	Maximum Score	Mean Score	Standard Deviation
2006	72,299	29.70%	200	80.63	73.00
2007	83,162	30.12%	200	82.63	35.00
2008	93,692	30.72%	200	73.42	35.43
2009	104,883	31.09%	200	62.62	34.02
2010	109,811	30.72%	200	70.22	35.73

Source: KNEC KCSE Examination Reports (2006 - 2010)

From Table 1, it can be observed that students' participation in physics reduces as they progress through education with enrolment in KCSE ranging between 29.70% and 31.09% of the total candidature. The mean students' performance in the examinations has also stagnated at scores between 62.62 and 82.63 out of a maximum score of 200.

The poor performance in the physics national examinations calls for intervention. This formed the basis of cooperation between the Government of Kenya (GOK) through Ministry of Education, Science and Technology (MOEST) and the Government of Japan (GOJ) through Japan International Cooperation Agency (JICA) since 1998 to build capacities of mathematics and science teachers through the Strengthening of Mathematics and Science in Secondary Education (SMASSE) Project. It was an intervention to address poor students' performance in mathematics and science subjects in the KCSE examination. The overall goal was to upgrade ability of secondary school students in mathematics and science through In-Service Education and Training (INSET) of teachers of these subjects to improve their teaching.

At the onset of SMASSE Project in 1998, a baseline study was conducted to identify factors responsible for poor performance in mathematics and science at secondary school level. The study identified negative attitude toward mathematics and science, poor teaching methodology, inadequate mastery of teaching subject content, inadequate teaching and learning materials that include ill-equipped laboratories, and school management among other factors (Waititu and Orado, 2009). The project technical team identified teaching methodology as the overriding factor and focused on INSET for teachers to improve their teaching practices. The project team designed an instructional approach known as ASEI-PDSI approach, an acronym for Activity, Student, Experiment, and Improvisation (ASEI) and Plan, Do, See and Improve (PDSI). This approach endeavours to shift teaching and learning from knowledge-based teaching to activity-based learning, teacher-centred teaching to learner-centred learning, expository to experiment, research and improvisation.

Concept mapping based instruction is one of the instructional strategies advocated by CEMASTEA as a learner-centred learning approach (Makoba, 2012). Concept mapping is a meta-learning strategy based on the Ausubel-Novak-Gowin theory of meaningful learning (Novak and Gowin, 1984). Its advantage lies on the fact that learning new knowledge is dependent on what is already known. It upholds that new knowledge gains meaning when it can be largely related to a framework of existing knowledge rather than being processed and stored in isolation. It mainly emphasizes the meaningful relationships between variables or sub-concepts in the main concept.

Concept mapping based instruction is considered an active rather than passive learning task, and it serves as an elaborative study activity when students are guided to construct concept maps in the presence of the materials they are learning. It requires students to enrich the material they are studying and encode meaningful relationships among concepts within an organized knowledge structure. Instructional concept maps also serve to reinforce students' understanding, and assess their achievement, among other educational applications.

In view of the immense contribution of concept mapping based instruction to the process of teaching and learning science and mathematics, it is an invaluable area for more research, particularly in the case of SMASSE's ASEI-PDSI implementation programme.

Purpose of the Study

The purpose of this quasi-experimental study was to determine if combining instructional concept mapping and conventional instructional techniques would improve students' achievement in physics, focusing on the topic 'electric current'. The research questions investigated in this study were as follows:

1. Does concept-mapping strategy improve students' achievement in Electric Current?
2. What are the roles of teachers and students in lessons employing concept mapping strategy and conventional instructional techniques?
3. What are the challenges encountered by physics teachers and students when using concept mapping strategy as compared to those using conventional instructional techniques?

This study focused on concept mapping as a learner centred approach and students' achievement in Physics in public secondary schools in Nairobi County. Achievement was evaluated on the basis of students' performance in achievement tests.

Various aspects of the teacher and the learner during physics instruction were considered. Among the teacher aspects included variation and integration of instructional strategies during physics lessons. These strategies range from teacher centred and interaction approaches to learner centred approach with main emphasis on concept maps.

On the other hand, learners' characteristics during the physics lessons were evaluated on their ability to integrate new knowledge to existing structures in order to retain knowledge and receive meaning of the concepts learned, and to identify gaps in knowledge. This involves diagnosis of misconceptions.

The findings of this study are limited to the sampled schools and may vary from the rest due to their unique characteristics and other factors that influence performance other than instructional techniques, such as attitude and motivation. The findings are also limited to the topic 'electric current' and the extent to which the guideline for using the concept mapping approach was adhered to.

Research Design

This study used quasi-experimental design using pre-test and post-test with a control group and experimental group. This research design was as shown in Figure 1. The following were considered the main variables of the study. The independent variable was "use of Instructional Concept Maps (ICM) and Conventional Instructional Techniques (CIT)" while the dependent variable was "Students' achievement in physics". The CIT included lecture, discussions, demonstrations, and laboratory experiments.

					KEY:
Experimental:	R	O_1	X	O_2	O_1 and O_3 – Pre-test
Control:	R	O_3	(X)	O_4	X Treatment
					(X) No Treatment
					O_2 and O_4 – Post-test
					R – Randomly selected

Figure 1: Research Design for the Study

Purposive sampling was used to select public secondary schools that offer physics curriculum at form three since they were the target population for this study. Stratified random sampling was then used to select the boys' and girls' secondary schools. In the sampled schools, Form Three physics students were purposively selected to consider the topic, *electric current*, which was being taught at this level. Random sampling was then used to select streams and assign them into experimental and control groups.

The participants in this study were four streams (whole classes) of form three physics classes. The boys' and girls' schools were represented by two streams each. Each stream had 33 students. One stream in sampled boys' school was assigned experimental group. The other one was assigned control group. A similar approach was used for sampled girls' school. The three physics teachers for the sampled streams were included in the study as research assistants.

Four validated data gathering instruments were used: (a) a classroom observation schedule, (b) a teacher questionnaire, (c) a student questionnaire, and (d) two physics' achievement tests; pre-test and post-test. These were free response style written tests consisting of 20 items to be answered in one hour and were used to measure the learners' performance in physics. The objective was to measure the students' knowledge on concepts of physics before and after the treatment. The pre-test was set from topics before electric current while post-test was set from the electric current topic. Both pre-test and post-test were set and moderated by a panel of three physics teachers. A table of specification was used to construct the test items and to ensure they were well balanced in terms of knowledge and skills tested (Maundu, Sambili and Muthwii, 2005). Content validity was achieved through subject matter expert's verifications based on the experts' opinion of experienced physics teachers.

The classroom observation schedule was used to gather data on the observed roles of teachers and students in lessons using ICM and those of CIT. The instrument was administered during the lessons. Student questionnaire was adapted and modified from Simonson (1984:302). It was used to gather data on the challenges faced by teachers and learners during instructional process. It consisted of a number of items on a Likert scale that required the participants to give a rating to a given statement on a scale of 1 (strongly disagree) to 5 (strongly agree). The reliability estimate of the questionnaire was determined during the pilot study and necessary modifications made on the items.

Data Collection Techniques

Pre-test on physics was given to both groups prior to the intervention. The pre-test result enabled the researcher to determine the equivalence of the groups' ability in physics concepts at the beginning of the study (Table 4.1), which is essential in the quasi-experimental method.

During the intervention, the experimental group was taught 'electric current' concepts using concept maps as a teaching and learning tool while the control group was taught the same concepts without using concept maps. Concept maps were drawn progressively by the teacher and students in line with the progress of the lesson. At the end of the lesson, an overview of the main concepts and their sub-concepts including their propositional links were produced. Students further worked in supervised groups to produce more concept maps for the same concepts learned during a lesson.

The classroom observation schedule was used to collect observed data on lessons employing instructional concept mapping and on those of conventional instructional techniques. The two groups in girls' school were taught by two assisting teachers through a coordinated team teaching while the two groups in boys' school were taught by one teacher. Participating teachers followed teacher's instructional guide to ensure that they adhered to the principles guiding the experiment especially the teaching methods while they taught the 'electric current' topic and its related concepts. It was to eliminate the possibility of the teachers introducing their biases. Both groups were given the post-test after completion of the topic. The questionnaires were then administered to the participating students and teachers.

Results and Discussion

The students' pre-test scores were used to calculate the mean, standard deviation and the standard error of mean of both the experimental and the control. The mean scores on the pre-test were very close for the two groups indicating the two groups were of equivalent ability in physics (Table 2).

Table 2: Pre-test Scores for Experimental and Control Groups

			Descriptive statistics			Levene's Test for Equality of Variances	
School	**Group**	**N**	**Mean (Max $\bar{x}$ =40)**	**Std. Deviation**	**Std. Error Mean**	***F***	***p***
A (Boys)	Experiment	33	17.18	4.8118	0.8252	0.0129	0.9100
	Control	33	16.76	5.1783	0.9014		
B (Girls)	Experiment	33	18.79	6.0247	1.0650	0.0609	0.8059
	Control	33	18.36	5.8085	0.9961		

Comparison between the mean scores was carried out using an independent-samples t-test. The *t*-test results showed that the difference was not statistically significant (Table 3). Therefore, the two groups in both schools were assumed to be equivalent with respect to their initial knowledge and understanding of physics concepts.

Table 3: Independent *t*-test Results on Initial Group Differences

		Independent t-test for Equality of Means						
School		**t**	**df**	**Sig. (2-tailed)**	**Mean Diff.**	**Std. Error Diff.**	**95% Confidence Interval of the Difference**	
							Lower	**Upper**
A (Boys)	Equal Variances	0.3447	64.000	0.7314**	0.4242	1.2305	-2.0341	2.8825
	Unequal Variances	0.3447	63.658	0.7314	0.4242	1.2305	-2.0348	2.8832
B (Girls)	Equal Variances	0.2913	64.000	0.7718**	0.4243	1.4568	-2.4860	3.3346
	Unequal Variances	0.2913	63.915	0.7718	0.4243	1.4568	-2.4869	3.3355

**Difference is not statistically significant, p>.05

The students' achievements of electric current concepts were investigated for both the experimental and control groups. Table 4 shows the descriptive statistics and Levene's test for equality of variances results on difference in students' achievements. The data were obtained immediately after the intervention and therefore this is considered as the immediate learning gain.

Table 4: Descriptive Statistics Results for Difference in Learning Gains

			Descriptive statistics			Levene's Test for Equality of Variances	
School	**Group**	**N**	**Mean (Max $\bar{x}$ =40)**	**Std. Deviation**	**Std. Error Mean**	***F***	***p***
A (Boys)	Experiment	33	21.18	5.3060	0.9100	0.4048	0.5269
	Control	33	18.48	4.7112	0.8201		
B (Girls)	Experiment	33	25.03	5.4514	0.9637	1.1255	0.2927
	Control	33	21.91	6.2016	1.0636		

An independent-samples t-test was conducted to compare students' achievement of the learned electric current concepts in ICM and CIT lessons. In boys' school, there was a statistically significant difference in the scores for experimental (M = 21.18, SD = 5.3060) and control (M = 18.48, SD = 4.7112) groups at the 5% level of significance; t (64) = 2.1834, p = 0.0327. Similarly, in Girls' school, the immediate mean gain score for the experimental group (M = 25.03, SD = 5.4514) was high compared to the control group (M = 21.91, SD = 6.2016) and the difference is statistically significant at the 5% level, t (64) = 2.1715, p = 0.0336 based on an equal variance independent *t*-test (Table 5).

Table 5: Independent *t*-test Results for Difference in Learning Gains

		Independent t-test for Equality of Means						
School		**t**	**df**	**Sig. (2-tailed)**	**Mean Diff.**	**Std. Error Diff.**	**95% Confidence Interval of the Difference**	
							Lower	**Upper**
A	Equal Variances	2.1834	64.000	0.0327*	2.6970	1.2352	0.2294	5.1646
(**Boys**)	Unequal Variances	2.1834	63.116	0.0327	2.6970	1.2352	0.2286	5.1654
B	Equal Variances	2.1715	64.000	0.0336*	3.1212	1.4374	0.2498	5.9926
(**Girls**)	Unequal Variances	2.1715	62.965	0.0337	3.1212	1.4374	0.2480	5.9944

*Difference is statistically significant, $p < .05$

The equal variance independent *t*-test was used after ascertaining that the two groups have similar variances as indicated by the *p*-value for the Levine's test that is greater than 0.05 (Table 4). The statistically significant difference in the *t*-test result means that the experimental group was superior to the control group suggesting the benefit of instructional concept maps on learning. Novak and Musonda (1991) showed that students taught using concept maps posses more valid science concepts and hold fewer misconceptions compared to students instructed using conventional methods.

Roles and Challenges of Teachers and Students in ICM and CIT Lessons

The primary role of a classroom teacher as an instructor is to plan and implement study lessons in a manner that helps students to develop and relate concepts. A teacher is supposed to teach areas of the curriculum, monitor, evaluate and report students' progress in key learning areas, and implementing strategies to achieve targets related to specific student learning outcomes. The research findings established the following; (a) teaching strategies commonly employed by teachers are teacher centered or interactive, and rarely learner-centered. Other than national examinations oriented experiments (practical), teachers rarely plan activity-based lessons; (b) teachers did not find difficulty in using instructional concept maps for the first time; (c) teachers rank high on their ability to prepare the learners before using a specific teaching strategy and that they demonstrated competence on the use of specific strategies/methods.

Further findings showed that; (a) teachers were able to review the lessons much better in ICM lessons than in CIT lessons, giving summary to the lesson during or at the end of the lesson. We can suggest that constructed concept maps gave a summary of the concepts learned during the lesson and made it easy for the teachers to review the lessons; (b) teachers were able to report/reinforce key points in the presentation immediately in ICM lessons unlike in CIT lessons where teachers mostly reported/reinforced key points at appropriate breaks. This is possibly because the level of teacher-student and student-student interaction in ICM lessons is relatively high and that immediate response is necessary in the process of constructing the concept maps; (c) the level of learners' participation and interaction with the teaching resource was high in ICM lessons compared to CIT lessons. This could be attributed to the fact that learners in ICM lessons worked in groups, and were directly involved in construction of the concept maps and teachers only served to facilitate the process. This shows that ICM lessons have the students at its centre in an active role and teacher in a passive, instructive role. We can also say that perhaps students' participation in the lessons, and interaction with learning resources and with each other in CIT lessons is only limited to question-answer sessions, discussion, teacher guided problem solving sessions and during experiments which are in themselves not adequate; (d) students in ICM lessons asked questions and sought guidance "a great deal". This was unlike in CIT lessons in which students "fairly adequately" asked questions or sought guidance.

Conclusions

Based on the study findings, the following conclusions were made. First, given that in the post-test, the mean difference between the two groups was large enough and the equal variance independent-samples t-test confirmed that the difference is statistically significant at 5% level of significance and 95% confidence level (interval), the study concluded that concept mapping instruction has a positive effect on students' achievement in physics.

Secondly, the study concluded that teachers commonly used teacher centered or interactive teaching methods mainly because they are either "not ready" or are unprepared to plan and implement activity-based or learner-centered lessons as advocated by SMASSE's ASEI-PDSI programme. Such activity-based lessons are slightly more involving in terms of time and effort to plan compared to teacher-centered or interactive based lessons. Teachers tend to prefer strategies based on ease of use of the strategies/methods.

Thirdly, instructional concept maps were viewed as a better way of summarizing concepts learned during the lesson thereby making it easy for the lessons to be reviewed and key points reported or reinforced as is required. Fourth, learners' participation is high in student centered learning. The level of students; interaction with the teaching resource and with each other is also high. This translates to active learning and students taking responsibility for their own learning.

Lastly, that the challenges teachers and students encounter during the lessons influence the quality of instruction. These challenges are the same for all teaching strategies/methods. However, most of these challenges are easy to overcome by adopting certain teaching strategies.

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