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Impact of Teaching Isotopes in Chemistry 5070 Using the Historic Approach on Zambian Grade 11 Pupils' Achievement and Motivation

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Abstract— **This action research explored the impact of the historic approach on pupils' motivation and achievement. The study involved two grade eleven classes studying Chemistry 5070 at a secondary school in in Zambia. The two classes had 104 pupils and out of these 34.6% were girls while 65.3% were boys. The study adopted a counterbalanced quasi-experimental design. The experimental group was taught using the historic approach combined with the lecture discussion method while the control group was taught using the lecture discussion method only. After teaching four lessons, the class that was the experimental group became the control group and the one that was the control group became the experimental group. Achievement was assessed using results from a chemistry test while the one that related to motivation was assessed using results from a questionnaire and classroom observations. A t-test was used to compare the counterbalanced groups at 95% confidence level. Results and findings obtained both from the achievement test and a questionnaire survey revealed that the historic approach contributed positively to pupils' achievement and motivation towards chemistry. Results of this study suggest that there were significant positive gains in pupils' motivation and achievement in chemistry when using the historic model. These gains were higher for the historic model compared to those obtained when using the lecture discussion method only.**

Index Terms— **Historic approach, isotopes, motivation, achievement, radioactivity, lecture discussion.**

I. Introduction

Chemistry is one of the key science subjects in the secondary school curriculum in Zambia in which there is low achievement in national school leaving certificate examinations.

In 2013, the Chief Examiner's report showed that the pass percentage in Chemistry 5070 was 60.4% and 60.8 % in 2012 and 2013, respectively. The unsatisfactory pass rates in Chemistry may be traced down to particular topics such as rates of chemical reaction and equilibrium, the mole concept, isotopy, and content on non-metals and organic chemistry [1]. For example, it was reported that radioactivity was one of the topics that was either not well taught or not well understood by learners. Consequently, candidates were not able to define or explain concepts such as radiation and isotope. At the heart of the problem was the pedagogical approaches that teachers employed [1].

It is important therefore to use innovative pedagogical approaches such as the historical approach and to demonstrate their impact in learning difficult concepts such as those associated with radioactivity and isotopy. It has been observed that the historic approach generally raises personal, ethical, sociological, philosophical, and political concerns that tend to increase interest and motivation in students [2] and [3]. The historic approach refers to the pedagogical style used by science teachers to reveal the historic development of specific scientific concepts in an effort to improve one's perception of the meaning, image, knowledge and nature of science [4]. Its efficacy has been demonstrated in several studies, in physics education [5], and chemistry education [6] and [7].

Monk and Osborn [8] developed a pedagogical model for including history and philosophy of science in the curriculum. Monk and Osborn argued that allowing students to construct their knowledge alongside historical ideas that relate to the phenomenon under study could promote meaningful learning and conform well to a curriculum based on nature, history and philosophy of science [8]. This approach enables contrasting between thinking then, and now, bringing in a sharper focus of the nature and achievement of our current conceptions. Allchin [9] suggested that the historic model can provides developmental themes and story lines, can help to identify potential misconceptions and ways to address them, can be used for teaching processes and skills and, can be used to portray role models.

II. PURPOSE OF THE STUDY

In Zambia, the aims of the Chemistry 5070 syllabus are many. Among other aims, it seeks to stimulate learners and sustain their interest in the leaning of chemistry, promote awareness of how scientific theories and methods have developed, and to appreciate that the study and practice of chemistry is subject to social-economic, technology, ethnic, and cultural influences [10]. It would seem that the use of the historic approach could help achieve some if not many of these aims. Monk and Osborn make the point that by examining early thinking about a scientific concept or idea might help students make sense of their own developing understanding [8].

This action research explored the use of the historical approach to teaching isotopes to grade 11 students following the syllabus of Chemistry 5070. This approach was meant to reveal historic views about isotopes while linking these facts to new trends and their uses in the nuclear energy plants. This research provides a case study of the application of the

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historical approach and its impacts on the two dependent measures: achievement and motivation. The study was planned around one general broad research question and two sub-questions:

1. Can the use of the historic approach to teaching isotopes contribute positively to increased motivation and achievement in pupils?
   a. What is the impact of using the historic approach when teaching isotopes on grade 11 pupils' motivation?
   b. What is the impact of using the historic approach when teaching isotopes on grade 11 pupils' achievement?

III. RESEARCH METHODOLOGY AND PROCEDURES

A. SETTING OF THE RESEARCH

The research was undertaken at a secondary school found in Chililabombwe district of the Copperbelt Province of Zambia. The Copperbelt province is one of ten provinces in Zambia and Chililabombwe district is one of ten on the Copperbelt province of Zambia. Chililabombwe district in 2016 had six secondary schools from which Chililabombwe Secondary School with 18 senior, i.e., grade 10-12, secondary classes was purposively selected. It was the only school originally gazetted as secondary school in the district and is recognised by the Ministry of Education as a "grade one secondary school". It was also the only offering the Chemistry 5070 syllabus while the other four secondary schools offered Science 5124, an integrated course of study. Two classes out of five at this school studied Chemistry 5070 and the rest Science 5124. The two classes, grade 11 S_1 and grade 11 T_1 were selected for the study. These were randomly assigned to the two intervention groups, lecture discussion and historical study, and lecture discussion only. Grade 11 S_1 had 51 learners (31 male and 20 female) and grade 11 T_1 had 53 learners (34 male and 19 female), and their average age was 16 years.

B. RESEARCH DESIGN

The study was an action research to implement and assess the impact of a historical approach on learner motivation and achievement when learning isotopes and radioactivity. The research design was a counter-balanced pre-test and post-test quasi experiment using two grade 11 classes. In the first phase a series of lessons were delivered to one grade 11 class where lecture discussion incorporated historic incidents and examples and the second class learnt the same material following lecture discussion only. In the second phase, the classes swapped, such that the second class became the experimental group using lecture discussion method incorporating historic incidents and examples.

Table 1: Study counter balanced pre-test post-test quasi-experimental design.

	Phase 1			*Phase II*	
Class	Pre-Test	Treatment	Post-test 1	Treatment	Post-test 2
Grade11 S1	1. AT 2. MQ	LDH	1. AC 2. MQ	LD	1. AC 2. MQ
Grade11 T1	1. AT 2. MQ	LD	1. AT 2. MQ	LDH	1. AC 2. MQ

AT = Achievement test; MQ = Motivation questionnaire; LD = Lecture discussion only; LDH = Lecture discussion & historical approach.

C. THE INTERVENTION

The intervention was a teaching and learning approach in which lecture discussion deliberately incorporated the historical approach in eight 80-minute lessons over a period of two weeks. Largely, the lessons followed the six-phase model that Monk and Osborn developed [8]. The basic features of the Monk-Osborn model are presentation of the phenomenon, elicitation of learner's ideas, historical study of material presented by the teacher or researched by learners, devising possible experimental tests of the ideas in the historical study, teacher presentation of scientific ideas, and review and evaluation. Stress was placed on the historical study and presentations that learners made to the whole class. Learners were provided with developmental themes, background information, a brief chronology of events, and some theories relating to discovery of isotopes and radioactivity. The learners were required to reflect on this information in particular the views of different important personalities associated with discovery of isotopes and radioactivity. These activities tried to ensure that learners came to realise that different people and scientists hold divergent views and that their ideas have undergone continual refinements over millennia. The learners also made short presentations about the topic to class members.

In phase one, content was based on isotopes in general, radio-isotopes, calculations involving relative atomic mass, and on alpha decay while in phase two the content covered beta decay, gamma decay, uses of radio-isotopes and the dangers of radio-isotopes. This was consistent with requirements prescribed in Chemistry 5070. The historic content of isotopes included their discovery, the people behind the discovery, the economic-social-political aspect that existed at that time, and the cultural aspect of the people behind the discovery of isotopes. The content area for the study was as prescribed in the Chemistry 5070 syllabus.

D. THE DEPENDENT MEASURES

The pre- and post-tests comprised of two researcher constructed instruments: (i) the achievement test covering content on isotopes and radioactivity and (ii) the questionnaire to measure motivation of students towards the content and teaching approach used. The test had twenty-seven questions. The content of the test based on stable isotopes and radioactivity. Motivation is an important construct that expresses students' attitudes relevant to put effort toward attainment of learning goals. Motivation was measured on a 26-item questionnaire developed by the researcher. The items used the Likert scale response format to express motivation linked with four factors, pedagogical value, active learning strategy, task value, and self-efficacy associated with teaching and learning following the historic approach.

IV. RESULTS AND FINDINGS

The results of analysing the data sets obtained are presented starting with those for achievement followed by those for motivation.

A. HISTORIC APPROACH AND ACHIEVEMENT

A researcher-developed test was used to assess learning of concepts associated with isotopes and radioactivity with the results summarised in Table 2. In the pre-test the two classes showed equal achievement scores.

Table 2: Achievement scores of learners in pre- and post-test in Phase I and II.

Class (n)	*Pre-Test* Mean (SD)	*Phase I*	*Post-test 1* Mean (SD)	*Phase II*	*Post-test 2* Mean (SD)
11T1 (n = 53)	46.74 (9.36)	LDH	54.72 (10.3)	LD	64.28 (9.48)
11S1 (n = 51)	46.47 (9.05)	LD	48.67 (8.30)	LDH	68.24 (7.95)

LD = Lecture discussion only; LDH = Lecture discussion & historical approach

The mean achievement scores of the two classes (Grade11 S1 M = 46.47, SD = 9.05; Grade 11 T1 M = 46.74, SD =9.36) were not significantly different (t = -0.147; p = .884). After the intervention in which the historical approach and lecture discusses were used with Grade 11 T_1 (M = 54.72; SD = 10.33) increase of +8 points was noted from pre-test to post-test compared to an increase of only +2.2 points in lecture discussion only. A t-test for equality of means showed that the mean difference of 6.050 was statistically significant ($t_{df\,=\,102}$ = 3.284; p = .001). This indicates that the class Grade11 T1 that combined lecture discussion and historical approach resulted in higher achievement scores compared to the class Grade11 S1 that utilised lecture discussion only to learn isotopes and radioactivity. In phase two of the intervention, the classes swapped such that Grade11 S1 now utilised lecture discussion and historical approach while Grade 11 T1 now utilised lecture discussion only. As shown in Table 2 the group means indicated that for the experimental group (Grade 11 S1 M =68.24, SD = 7.95) and that of the control group (Grade 11 T1 M = 64.28, SD =9.48). The difference (3.952) in the achievement between the two classes was statistically significant ($t_{df\,=\,102}$ = 2.30; p = 0.023). The class in which lecture discussion and historical approach were used still produced higher achievement gains compared to the class that utilised the lecture discussion without historical referents. What is also interesting to note is the gain of +21.77 gain in achievement score from pre-test to final post-test (phase 2) in the class (Grade 11 S1) which started with lecture discussion followed by lecture discussion and historical approach. The gain for grade 11 T1 that started with lecture discussion and historical approach and later switched to lecture discussion only was +17.52.

B. HISTORIC APPROACH AND LEARNER MOTIVATION

A researcher-developed questionnaire was used to assess motivation towards the teaching and learning approaches and for concepts associated with isotopes and radioactivity with the results summarised in Table 3. Learners were to express the degree of agreement or disagreement to the 26 questionnaire items on the scale: 1 strongly agree, 2 agree, 3 uncertain, 4 disagree, and 5 strongly disagree. They tended to disagree to items that suggested that learning about isotopes and radioactivity or the scientists who discovered them was interesting or important. Learners responded quite consistently to the items. For example for learners in 11T1, the score on a negatively stated item 1 "It is not important to understand how early chemists studied isotopes and radioactivity during lessons" was 3.87 (learners disagreed to it). On the equivalent positive item 3 "Understanding how early chemists studied isotopes and radioactivity as we learn is important" the score was 2.09 (learners agreed).

Overall, the learners in the two classes expressed a more favourable disposition to learning about early scientists and their discoveries, the development and refinement of ideas over time, and rated favourably their self-esteem and confidence with the topic. These favourable dispositions were more likely to be found among learners taught via lecture discussion and historical approach compared to when no historical referents are made. For example, on item 4 "I enjoy learning about isotopes and radioactivity better when I understand its development over time", the mean score for the historical approach class was 1.94 (agree) compared to 3.24 (disagree) for the lecture discussion only class. On self-esteem and confidence, the class that used the historical approach tended to be more positive in the first phase. For example, the scores for the historical class (11T1) and lecture only class (11S1) were respectively, 2.36 (agree) and 3.61 (disagree) on the item "I am confident about understanding difficult concepts on isotopes and radioactivity when they are taught", and respectively, 3.55 (disagree, 11T1) and 2.22 (agree, 11S1) on the item "My self-esteem is low when I am learning about isotopes and radioactivity". Table 4 shows the results of the overall analysis of the learners' responses to the questionnaire. In order to obtain the total scores on the 26 questionnaire items, the Pallant procedure was employed [11].

Table 3: Motivation scores of learners in pre- and post-test in Phase I and II.

Class (n)	*Pre-Test* Mean (SD)	*Phase I*	*Post-test 1* Mean (SD)	*Phase II*	*Post-test 2* Mean (SD)
11T1 (n = 53)	90.94 (7.46)	LDH	55.81 (23.30)	LD	55.62 (23.60)
11S1 (n = 51)	91.62 (6.83)	LD	85.27 (16.69)	LDH	55.73 (24.55)

LD = Lecture discussion only; LDH = Lecture discussion & historical approach

On the scale, the lowest score of 26 reflected the highest motivation (or 'strong agreement' to the questionnaire items), 78 reflected 'uncertain', and 130 reflected the lowest motivation (or 'strong disagreement' to questionnaire items). The scores obtained by grade 11 T_1 (the experimental group using the historical approach combined with lecture discussion; mean = 90.94; s = 7.46) and grade 11 S_1 (the control group using the lecture discussion method only; mean = 91.62; s = 6.83) were not significantly different ($t_{df = 101}$ = 0.479; p = .633). These scores suggest that learners tended to display low motivation for the topic isotopes and radioactivity.

Results in Table 3 show that the post-test group means indicated that grade 11 T_1 (the experimental group using the historical approach combined with lecture discussion (M =55.81, SD = 23.302) and that of grade 11 S_1 (the control group using the lecture discussion method only) (M = 85.27, SD = 16.685). The group using the historical approach showed higher motivation gains from pre-test to post test (+ 35.13) compared to the lecture discussion only group without historical referents (+ 6.35). Overall, the group that used the historical approach had gained some 28.78 motivation points over the class not taking the historical approach. In an independent group t-test, the Levene test for equality of variances showed a significant difference in variances (F = 21.01; p = .000) and thus assuming unequal variances in the two classes, their motivation scores were significantly $t_{df = 94.33}$ = 7.435, p = 0.00). In the second phase of the study, grade 11 S_1 became the experimental group while grade 11 T_1 became the control group with the results in Table 4. The results showed that the motivations scores for the experimental group (mean = 55.73; s = 24.55) and the control class (Mean = 55.62; 23.60) were comparable and not statistically different ($tdf_{= 102}$ = 0.022; p = .983).

V. DISCUSSION AND IMPLICATIONS

This study has shown some evidence that students taught by lecture discussion without historical referents and those taught by the historic approach combining lecture discussion and historical referents produced positive gains in achievement and motivation from pre- to post-test. However, the class that used historical referents gained more significantly in knowledge of isotopes and radioactivity than when such historical referents were excluded. Further, after the classes swapped such that the one that had served as control was made the experimental group, the achievement scores were both high and not significantly different. This suggests that once the students gained foundational knowledge on isotopy and radioactivity via historical referents they continued to learn productively even if the historical referents were not part of lecture discussions anymore. When the historical approach followed the development of foundational knowledge through lecture discussion, it raised the learning gains of the class substantially. It would seem that the incorporation of the historical approach results in learning gains to develop and advance foundational knowledge necessary for sustained productive learning. The trends in achievement observed were comparable to the patterns seen in the motivation scores among students suggesting that use of the historical approach influenced attitudes towards teaching and learning of isotopes and radioactivity favourably too.

This study adds to the sheaf of research findings in support of historical approaches in science education [2], [3], [5], [6], and [7]. The historic approach works because of the motivation it provides to students and because it humanises the study of science by bringing to attention people who made significant contributions to science and society. Besides, it drives the teacher who wants to incorporate it to be creative and innovative in identifying examples and their applicability to the current lessons. For example, in this study, the teachers had to integrate video vignettes of Henri Becquerel and Mary Curie who pioneered the work on radioisotopes. The teachers became innovative too in encouraging student research, student-student discussions and allowing the results to be presented to the class. Overall, the students became more actively involved. The anecdotal evidence in this study suggests that the incorporation of historical approach influenced the teacher's pedagogical practices to become student-centred, a point that merits further research. Metz, Klassen, McMillan, Clough, and Olson point to the importance of imagination and creativity to avoid dull and uninspiring lessons that miss the relevance of using the historical approach [2].

CONCLUSION

The results and findings of this study suggest that the impact of using the historic approach combined with the lecture discussion method on achievement and motivation of pupils was positive than using the lecture discussion method only. Besides improving achievement and motivation of their learners in content related to isotopes and radioactivity, the results may have relevance to improving performance achievement in science in general. While there are these benefits in using historical approaches, there is a clear need for the creativity, imagination and innovation of teachers who use it. This will enable them to contextualise learning material and to discuss contemporary issues and stress significant intellectual achievement and the impact of the scientific contribution to the development of technology and society.

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