A CORRELATION STUDY OF SECONDARY STUDENTS ACADEMIC ACHIEVEMENT IN CHEMISTRY AND THEIR SCIENTIFIC CREATIVITY IN CHEMISTRY

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ABSTRACT

The present study is an attempt to study secondary school students' academic achievement in Chemistry in relation to their scientific creativity in chemistry. Simple random sampling technique is used in the selection of sample. In the present investigation a sample of 721 higher secondary students from 4 counties in Kenya were selected. Two validated tests were used; Chemistry Achievement Test (CAT) was used to assess student's academic achievement while the Chemistry Scientific Creativity Test (CSCT) was used to asses learners scientific creativity in chemistry. Results showed that there is a positive and significant correlation between academic achievement in chemistry and scientific creativity in chemistry.

KEY WORDS:

Academic Achievement, Scientific creativity, Chemistry.

INTRODUCTION

The concept of creativity has been used frequently in various fields of study with different meanings. According to Treffinger, Young, Selby and Shepardson (2001) creativity is the ability to generate ideas digging deeper into ideas, openness, and courage to explore ideas and listening to one's inner voice. It is an open exploration or search for ideas in which one generates many ideas (fluency in thinking) varied ideas and new perspective (flexibility) and unusual or novel ideas (originality). Creative individuals are divergent thinkers (Guilford, 1959). Guilford performed important work in the field of creativity, drew a distinction between convergent and divergent production (commonly renamed convergent and divergent thinking). Convergent thinking involves aiming for a single, correct solution to a problem, whereas divergent thinking involves creative generation of multiple answers to a set problem. Divergent thinking is sometimes used as a synonym for creativity in psychology literature. Divergent thinking is taken to be the cognitive to generate ideas (Treffinger, 2002).

Other researchers have occasionally used the terms flexible thinking or fluid intelligence, which are roughly similar to (but not synonymous with) creativity. Some see the conventional system of schooling as "stifling" of creativity and attempt (particularly in the pre-school/kindergarten and early school years) to provide a creativity-friendly, rich, imagination-fostering environment for young children. The measurable characteristics associated with general creativity are fluency, flexibility, originality, elaboration and metaphoric thinking. (Guilford, 1959, Torrence, 1974).

Scientific creativity depends not only on a well-oiled imagination coupled with habits of hard work but, more importantly, on the ability to integrate in functional ways a wider range of ideas, concepts and skills than is usual. Freeman (1971) stated that creative development can be enhanced through the use of discovery methods. Sommers (1961) found out that in Industrial arts training that using discovery method may lead to superior performance in subject matter as well as gain in creative productivity. Torrance (1961) argues that perhaps the most promising areas if we are interested in what can be done to encourage creative talent to unfold, is that of experimentation with teaching procedures which will stimulate students to think independently, to test their ideas and to communicate them to others. Therefore the role of the teacher is to guide and facilitate learning rather than to tell.

According to Piaget (1970) "telling is not teaching". Moreover the teacher must be able to establish an environment that is leaner centred that facilitates collaborative as well as independent learning that encourages taking risks, that fosters problem solving and critical thinking (National Research Council, 1996). According to Okere, Changeiywo and Illa, (2010) concept mapping teaching strategy was found to inculcate scientific creativity in students. The findings of the study by Okere *et al* was that concept mapping teaching strategy enhances student's abilities of recognition of relationships and planning for scientific investigations. Recognition of relationships and planning for scientific investigations are some of the aspects of creativity in science (Okere, 1986). Scientific and general creativity are influenced by many factors such as intelligent quotient (IQ), social-economic status among many others. This study investigated the relationship between academic achievement in chemistry and chemistry scientific creativity in Kenyan secondary school students. Four aspects on scientific creativity were studied; Planning, Flexibility, Recognition of Relationships and Sensitivity.

OBJECTIVE OF THE STUDY

- To establish the relationship between learners' scientific creativity in chemistry and academic achievement in chemistry.

HYPOTHESIS

There is no statistically significant relationship between learners' scientific creativity in chemistry and academic achievement in chemistry.

1. METHOD

1.1 Research Design

The research design was mainly descriptive study. Descriptive research design was found to be appropriate since it can be used to determine the nature of prevailing conditions or relationships and practices that exist (Cohen & Manion, 1987).The research method of the study was cross-section survey since information collected was drawn from predetermined population (Borg & Gall, 1989). Its main purpose is to explore and describe the variable under the study (Kathuri & Pals, 1993, Cohen & Manion, 1987).

1.2 Sample

The guidelines given by Gall, Borg, Gall (1996) was adapted in determining the sample size. Where correlation coefficient (r) is used to test hypothesis at 0.05 level of significant, a minimum sample of 384 cases is required. When the independent sample t test is used, a minimum sample of 386 is required (Gall, Borg, Gall 1996). In view of this, a sample of 711 students was selected for the study.

Simple random sampling was used to select 8 secondary schools involved in the study. These schools were selected from 4 counties in Kenya. These schools formed the sampling frame in the random sampling of the study sample of 711 students of which 296 were boys and 415 were girls.

1.3 Instrumentation

Two instruments were used in the study;

1.3.1 Chemistry Achievement Test (CAT). The CAT had 30 items on chemistry concepts taught in secondary school. All the items were open-ended and were drawn from all the topics taught in secondary school. It was aimed at assessing learners' academic performance in chemistry. Items in CAT were not scored dichotomously, scores ranged from 1- 5 marks. The maximum score of the test was 100% while the minimum was 0%.

1.3.2 The Chemistry Scientific Creativity Test (CSCT) was used to determine scientific creativity in chemistry. The test had 13 items some (10) formulated by the researcher and some (3) adapted from the Assessment of Performance Unit (A. P. U.) tests. All the items in the CSCT were open-ended with each question testing one of the 4 aspects of scientific creativity. The test was aimed at assessing Form Three learners' competence in scientific creativity aspects which include;

a) Recognition of relationships

b) Flexibility

c) Sensitivity to the problems

d) Planning of investigation in chemistry.

2.0 MEANINGS OF GENERAL CREATIVITY

According to Treffinger, et al, 2002, Ed. creativity is ability to generate; ideas (fluency in thinking), varied ideas and new perspectives (flexibility) and unusual or novel ideas (originality). All these are aspects of divergent thinking where divergent thinkers move away from responses already known and expected. The other aspects are elaboration and metaphorical thinking (sensitivity to defect and missing elements). All this aspects are measurable.

3.0 PSYCHOLOGICAL MEANINGS OF SCIENTIFIC CREATIVITY THAT HAVE RELEVANCE TO SCIENCE EDUCATION

Meanings of Creativity that have Relevance to Science Education

Okere (1986) has summarized the psychological meanings or aspects of creativity that have relevance to science education under the following headings: sensitivity to problems, recognition of relationship, flexibility in reasoning and planning for investigations.

3.1. Sensitivity to Problems

This is defined as the ability to be aware of problems and think of possible solutions to the problems (Guilford, 1950; Torrance, 1959; Oche, 1990). This ability may be assessed in chemistry by setting problems that require students to identify inadequate scientific arguments, state possible sources of experimental errors, or criticize given experimental procedures. This is what Hu and Adey (2002) categorises as scientific problem solving sub-dimension of the Product (scientific product) dimension of SSCM. Lubart (1994) pointed out that problem solving can lead to creativity because if a problem exists then there is the possibility of creative solution. Hu and Adey (2002) state that sensitivity to science problems is also considered a component dimension of scientific creativity. Ochse (1990) argued that sensitivity to problems is an important feature of the creative process. According to Cattell (1971) problem solving does not mean solving routine problems using a recipe but finding the answers to new problems. Einstein and Infield (1938) suggested that the formulation of a problem is often more important than its solution, which may be a matter of mathematical or experimental skill. Okere (1986) gives scientific meanings of creativity that maps sensitivity to the problem as design of investigation. This includes the following activities;

3.1.1 Reformulating General Statements

In this case a student should be able to rephrase statements in such a way that they could be checked scientifically. This means that a student should first be able to identify the inadequacy of a given statement and also suggest an experiment that could be used to check the rephrased statement and control variables.

3.1.2 Criticizing Experimental Procedure

In this case the student should be able to identify what is wrong with an experimental procedure. The student should be able to identify the variables that need to be controlled to make the results of the investigation fairer, and explain the need to control such variables.

3.1.3 Describing the Sequences of Investigation

Here the student should be able to describe a given experiment that would be used to investigate a particular problem. In doing this, a student describes the sequences of investigations and explains the criteria to be used in determining the dependent variables.

3.1.4 Devising and Describing Investigations

Here the student is not given the outline of an experimental procedure to be followed hence a student is expected to decided what experimental procedure to use.

3.2. Recognition of Relationships

Physiologists suggest that a creative individual should be able to recognize relationships among concepts and retrieve earlier experiences whenever he encounters novel situations (Rogers, 1954; Bruner, 1957; Cropley, 1967).This ability can be assessed best by problems that require the application of chemistry concepts to everyday problems.

Brunner (1957, 1963) argues that a creative individual should not see data as unique but as part of related sequence of events which the environment has been providing. Okere (1986) gives recognition of relationships scientific definition as generating hypothesis. For a student to be able to generate hypothesis he needs to have an understanding of scientific phenomena. According to Okere (1986) generating hypothesis involves;

3.2.1. Selecting a Correct Hypothesis from Given Alternatives

In this case the student should be able to select a correct hypothesis from given alternatives. This will require a student to first recognise relationships between particular chemistry concepts and the expected outcomes before selecting the correct hypothesis. The student should also give reasons for whatever choice they made.

3.2.2 Generating a Hypothesis from a Particular Topic Area

Here the student suggests causes of given physical phenomenon or described observations. This requires the student to generate a hypothesis based on particular topic and give reasons for deciding on the particular hypothesis.

3.2.3 Generating a Hypothesis from Many Topic Area

In this case the student should elicit many possible hypotheses from various science topics when explaining causes of observed phenomenon. In this study the focus will be on the assessment of the above skills among Form Three chemistry students in National schools.

3.3 Flexibility in Reasoning

This is defined as the ability to produce a great variety of ideas even when it is not necessary to do so (Guilford 1950; Barron, 1969; Kuhn, 1959). Hudson (1990) and Torrence (1990) give a case for flexibility, fluency and originality. According to Wilson (1954) there are two types of flexibility.

- Spontaneous flexibility, which is the ability to produce a great variety of ideas, with freedom from inertia.
- Adaptive flexibility which facilitates the solution of problems

Okere (1986) state that the ability can be assessed by problems that calls for reasoning so that students have the freedom to give all possible reasons. Alternatively it may be assessed by design problems that give room for various ways of solving a particular problem. The scientific definitions of flexibility are design of investigations where general statements are formulated and generating hypothesis.

3.4. Planning for Scientific Investigations

The ability to devise experiments to test hypotheses (Parnes, 1963; Hudson 1967 & Washton, 1966).This skill can be assessed by constructing problems that require the identification of control variables. It can be displayed in problems that require students to propose and devise experiments to test hypothesis. The scientific definition of planning is design for investigation. This involves;

3.4.1 Reformulating General Statements

In this case a student should be able to rephrase statements in such a way that they could be checked scientifically. This means that a student should first be able to identify the inadequacy of a given statement and also suggest an experiment that could be used to check the rephrased statement and state the control variables.

3.4.2 Criticising Experimental Procedures

In this case the student should be able to identify what is wrong with an experimental procedure. The student should be able to identify the variables that need to be controlled to make the results of the investigation fairer, and explain the need to control such variables.

3.4.3 Describing the Sequences of Investigation

Here the student should be able to describe a given experiment that would be used to investigate a particular problem. In doing this, a student describes the sequences of investigations and explains the criteria to be used in determining the dependent variables.

According to Okere (1986, 1996), the above psychological definitions of creativity and their scientific meanings or definitions are displayed in his model shown in Figure 3. This model will guide the development of Chemistry Scientific Creativity Test (CSCT) which will be used in this study to measure the level of scientific creativity in chemistry education of form three students.

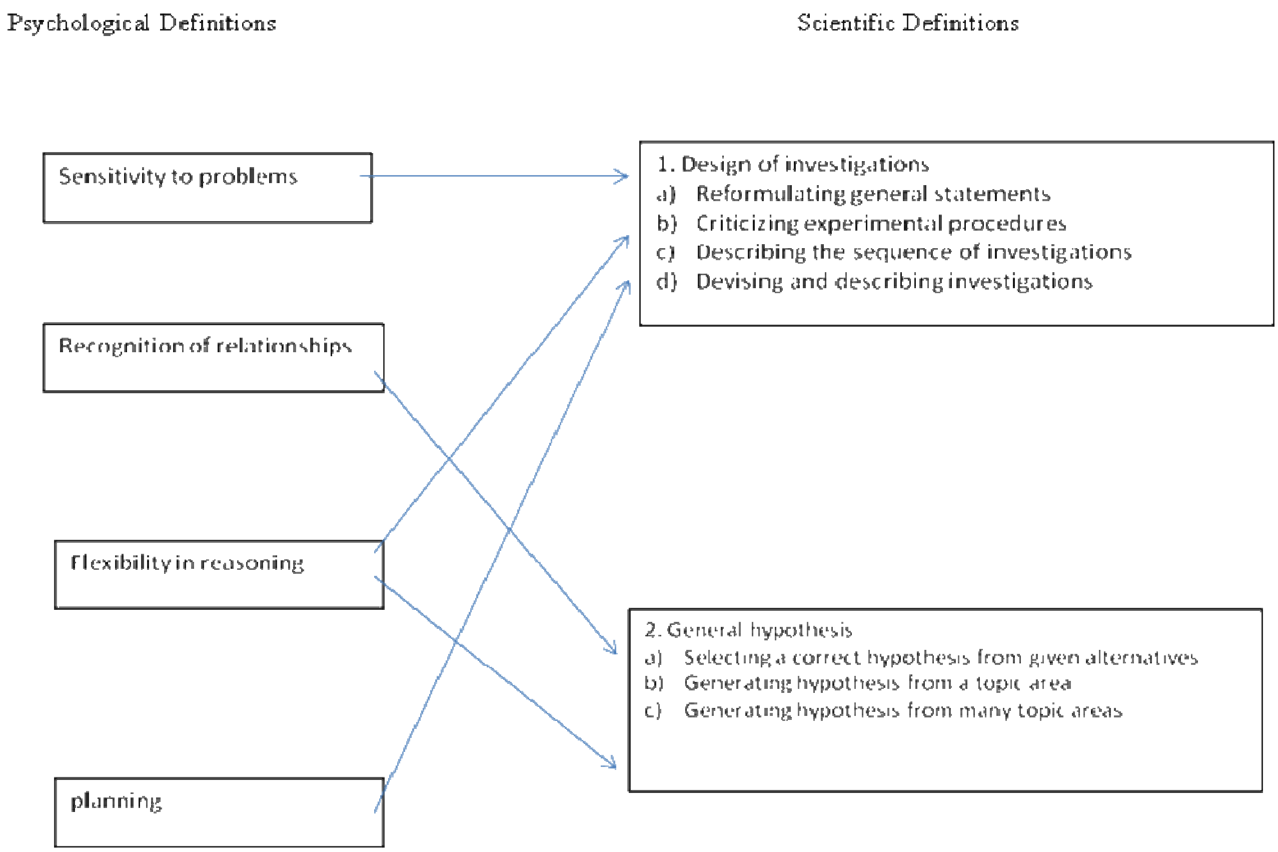

Figure 1: The mapping of psychological definitions of creativity onto scientific meaning (Okere, 1986)

4.0 SAMPLE ITEMS ON EACH ASPECT OF THE PSYCHOLOGICAL MEANINGS OF SCIENTIFIC CREATIVITY

1. **Sandra a form 3 student in Lions Secondary School has been given 5 bottles labelled P, Q, R, S and T with colourless liquids in them. She is told that 2 of the liquids are dilute acids, 1is an alkali and the other 2 are water. She also has a liquid indicator called phenolphthalein. This goes;**

   - **colourless in acids**
   - **red in alkali**
   - **colourless in water**

   Write some instructions for Sandra so that she can find out whether the liquid in each bottle is an alkali, acid or water. She is allowed to use a rank of test-tubes, the indicator and the liquids from the bottles P, Q, R, S and T. (10 Marks)

   NB: Make sure you say exactly what she must do so that when she has finished she can label the bottles 'Acid", 'Alkali", or 'Water".

This test question was testing 2 aspects of creativity namely planning and flexibility. 10 responses were required each scoring half a mark for score of 5 marks for planning and 5 marks for flexibility for a total score of 10 marks.

2. **Rehema complained of a burning sensation (hurt burn) along her food pipe (oesophagus) after lunch. Her chemistry teacher told her it was as a result of excessive production of hydrochloric acid in the stomach. She was advised to chew anti-acid tablets (actals). After a few minute the burning sensation stopped. Different parts of this question measured different aspects of creativity.**

   a) **Explain why the burning sensation stopped after taking anti-acid tablet. (2 marks)** This test item was measuring the recognition of relationship aspect of creativity.

   b) **Rehema attempted to determine the p^H of the actal tablets in the laboratory to prove the answer in (a) above. However she failed to get the p^H. Suggest as many as possible the mistakes Rehema did that made the experiment to fail. (10 marks)**

This test item was measuring two aspects of creativity sensitivity and flexibility. For every correct response given one mark was given for sensitivity and a mark for flexibility.

   c) **Describe to Rehema how she could determine the p^H of the ant-acid tablet (actal) in the laboratory. (10 marks)**

This test item was measuring two aspects of creativity, planning and flexibility. Planning aspect was measured by correct description of the steps in the procedure of measuring the pH of the tablet. 10 steps are used. Each correct step given ½ a mark in the correct sequence was awarded. Incorrect sequence was not awarded marks. Any wrong response in the sequence made the rest of the responses wrong because it would not have resulted in the determination of the Ph. The maximum score for this aspect of creativity (planning) was 5 marks.

Flexibility was measured by how many correct responses were given. For every correct response given ½ a mark was awarded. The maximum score on flexibility was 5 marks.

5.0 PILOTING

The test was piloted with 160 Form Three students in two schools (two National and two District school) with the same characteristics as the sample schools from Nakuru County. A specialist in scientific creativity and science education will moderate the CSCT items and the scoring key before and after piloting. Maximum score in CSCT was 100% while the minimum was 0%.

6.0 DATA ANALYSIS AND INTERPRETATION

Creativity in chemistry was measured by the Chemistry scientific creativity test (CSCT) while the chemistry achievement test (CAT) was used to measure achievement in chemistry. Learners' scores in the CSCT and CAT were expressed in percentages then used to calculate the mean scores which were then correlated. The SPSS programme was used to compute the Person Product Correlation Coefficients for the mean scores obtained from the two scores. The results are shown in Table I.

Mean scores in CAT and CSCT were correlated to establish whether there is a relationship between academic achievement in chemistry and scientific creativity in chemistry.

Table I

Person Product Correlation Coefficients for Learners' Scores on the Chemistry Scientific Creativity Test and Chemistry Achievement Test

	Mean	Std deviation	Scores on CAT	Scores on CSCT
Scores in CAT	28.47	17.37	1.00	0 .73**
Scores in CSCT	21.95	12.93	0 .73**	1.00

** Correlation is significant at the 0.05 level

The results in Table 1 show that the mean in CSCT was 21.95 with a standard deviation of 12.95 and CAT had a mean of 28.47 with a standard deviation of 17.37. The Person Product Correlation Coefficients for learners' scores on the chemistry scientific creativity test and chemistry achievement test scores r = 0.73, which was statistically significant at 0.05 level. This means that the means of CSCT and CAT are positively correlated and the correlation is significant. This implies that a good mastery of chemistry concepts is essential for development of scientific creativity in chemistry. Therefore, the null hypothesis is rejected.

7.0 DISCUSSION

The finding in Table 1 shows that there was a positive correlation between the learners' scores on the Chemistry achievement and the chemistry scientific creativity test and the correlations was statistically significant. This suggests that high achievement in chemistry which in turn means a good mastery of chemistry of chemistry concepts is essential for effective acquisition of chemistry scientific creativity. These findings are in agreement with findings of some researchers such as, Ai, (1999); Asha, (1980); Getzels & Jackson, (1962); Karimi, (2000); Marjoribanks, (1976); Murphy (1973); Yamamoto, (1964), Okere, (1986), (1988), Ndeke, (2012), Hungi, (2009) found that there is a relationship between creativity and academic achievement. Others like Weiner (2002) argues that the knowledge functions as a pre-requisite to creating anything while Dunbar (1999) in support to this suggests that knowledge is a pre-requisite for creative production in science.

8.0 IMPLICATIONS

The findings of this study indicate that student academic achievement in chemistry plays a significant role in developing or enhancing scientific creativity in chemistry. This is seen from the findings of this study which showed a positive correlation between learners' chemistry scientific creativity and chemistry academic achievement. Therefore, educational institutions should strive to improve students' academic achievement in chemistry as a strategy of posting or enhancing scientific creativity in chemistry.

9.0 CONCLUSIONS

There is a positive correlation between student's academic achievement in chemistry and their level of scientific creativity in chemistry. Students with in scores in chemistry academic achievement had high level of scientific creativity in chemistry. Therefore if teachers and educational institutions wish to enhance scientific creativity in chemistry education then they should ensure learners understand the chemistry concept taught in the classroom. Knowledge in chemistry which can be shown by academic achievement in chemistry tests and examinations is a requirement or pre-requisite to creativity in chemistry education.

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