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Abstract

Purpose: Science, technology, engineering, and mathematics have been identified to be the important competencies needed by a country for the twenty-first century skills for economic growth. A critical question addressed in this paper concerns the conceptual understanding of science by the teachers of Uganda. This conceptual inquiry is important to position the teaching of science to be a vehicle for the economic growth of Uganda.

Methodology: We carried out a survey using a random sample of one hundred teachers around Kampala and listed their responses to the questions "what is science?" and "what is mathematics?" The answers are compared to the reviewed "science", "mathematics" and the "scientific method" and it is established that the Uganda teachers lack the conceptual understanding of science and mathematics.

Results: Using the triangulation method, we generate the definition of science out of the collected definitions which tallies with the "scientific method".

Recommendation: We recommend that teachers are grounded in the understanding of the practice of science in their teaching of science and mathematics to promote economic growth.

1.0 Introduction

The conceptual understanding of science and mathematics by teachers has been sidelined by several researchers who have instead concentrated on the conceptual understanding of science and mathematics by the student and other causes of poor science academic performance. The focus of the research has been in the areas of gender bias, lack of qualified teachers, lack of instructional materials, subject nature, low student interest, lack of motivation, locus of control, self-efficacy, interest in schooling, self-concept, self-esteem, self-confidence, self-regulation, study habits, teaching strategies, motivation, laboratory use, content knowledge, and noncompletion of the science curriculum in a year. Content knowledge is divided into procedural fluency and conceptual understanding (Balka & Harbin, 2001). Procedural fluency is rote learning while conceptual understanding includes synthesis of concepts for application in day to day living. Given that the reviewed studies concentrated on other causes other than the "conceptual understanding of science", this study chose to carry out a survey on the subject to understand further the cause of the persistent poor science academic performance.

The survey carried out among one hundred teachers in and around Kampala by this study revealed that Uganda teachers have a conceptual problem of science and mathematics. The conceptual understanding of science is important for the teaching of science from the foundations. The demonstrative application of science concepts to everyday life has the stimulus for integrating learning with doing which is important for problem solving and innovation. Problem solving and innovation are important for bridging the technological gap between the developed and underdeveloped countries to resolve the problem of the skewed balance of trade. This will improve the balance of payment and lead to Uganda‟s economic growth.

1.1 Statement of the Problem

The conceptual understanding of science by the Uganda teachers is lacking. This contributes to the poor science academic performance of students. Science academic performance among schools in Uganda continues to register appalling results with 60 percent of students reported to have failed sciences in the 2014 senior secondary results. This habitually translates into low science enrolment in tertiary institutions. The Uganda National Academy of Sciences put it at a sad 1.15% said to be too low for industrial and therefore economic growth (UNAS, 2010). The conceptual understanding of science and mathematics is critical for reorientation of the pedagogy to science and skills development. The conceptual misunderstanding of science and mathematics by the teacher would translate into the conceptual misunderstanding of science and mathematics by the student. This could lead to habitual poor student academic performance. This needs correction to engender skills development, narrow the technological-gap and correct the chronic balance of payment deficit due to skewed international trade which favors excess imports.

1.2 Objective

To analyze the teacher conceptual understanding of science and mathematics in Uganda with the aim of improving science teaching and student science academic performance for increased enrolment into science courses for innovation and skills development for economic growth.

1.3 Hypothesis

Teachers lack the conceptual understanding of science

2.0 Literature review

The Government of Uganda has since 1997 financed academic (MOE, 2004; and Jane, 2008) and science reforms (UNCST, 2010; HEST, 2012) geared at improving science academic performance. This is intended to raise the capacity of the students to enroll for science courses. Although the Government has invested substantial resources in these interventions, the released Uganda Certificate of Education (UCE) results have consistently indicated poor results in mathematics and sciences with distinction one and two, on the average representing only three percent of the total candidates (UNEB).Uganda has a National Policy on science education, a National Science and Innovation (STI) Policy and a National Science, Technology and Innovation Plan. The policy also prioritizes science education at all levels under which sciences are compulsory subjects at Ordinary-Level. The policy is aimed at cultivating a science-based labour force for the country. Education is a right enshrined in the Constitution of Uganda and Article 30 stipulates that, education for children is a human right, and in article 34, children are entitled to basic education by the state and parents. Therefore the government would be implementing its civil duty by guaranteeing education and science aspirations of the nation.

Science aims at providing synthetic descriptions of as many as possible aspects of the world, endowed with as great as possible explanatory and predictive power. To this end, entities, models and theories have been constructed and successively refined, constrained by the necessity of internal consistency and their confrontation with “the intransigent world of brute reality” (Ogborn, 1997). It follows that learning science cannot be envisaged as a mere memorizing of “facts”. To benefit from the synthetic and parsimonious character of scientific explanations, that is to be able to analyze many particular facts at a time, there is a price to pay: understanding and handling non trivial relationships between different concepts, which are necessarily abstract. Conceptual understanding, which permits one to transfer an explanation of a phenomenon to different variants of a situation that have been previously analyzed, is clearly a goal to be recruited under the label “learning science”, at any level. Moreover, learning objectives about science should encapsulate ideas about the way scientists work, and how scientific knowledge proceeds, if the learner is to have an idea of what is science (Viennot, 2003).

Conceptual understanding allows a student to apply and possibly adapt some acquired mathematical ideas to new situations. Mathematics as the queen of science cannot be completely separated from sciences because of its application to physical sciences. Increasingly, applicants for the best employment opportunities will need a good grasp of science, mathematics, and computer technology. However, the societal values and views about its importance among the school subjects have not been fully explored. Why this is so, and what can be done to increase their achievement, are important educational concerns now (Sikiru, 2012).Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge. For decades, the major emphasis in school mathematics was on procedural knowledge, or what is now referred to as procedural fluency. Rote learning was the norm, with little attention paid to understanding of mathematical concepts. Rote learning is not the answer in mathematics learning, especially when students do not understand the mathematics. Students demonstrate conceptual understanding in mathematics when they provide evidence that they can recognize, label, and generate examples of concepts; use and interrelate models, diagrams, manipulatives, and varied representations of concepts; identify and apply principles; know and apply facts and definitions; compare, contrast, and integrate related concepts and principles; recognize, interpret, and apply the signs, symbols, and terms used to represent concepts. Conceptual understanding reflects a student's ability to reason in settings involving the careful application of concept definitions, relations, or representations of either (NCTM, 2000).

Patronizingly, the main focus of most reviewed literature is on the conceptual understanding of the student. When students have an understanding of a concept, they can (a) think with it, (b) use it in areas other than that in which they learned it, (c) state it in their own words, (d) find a metaphor or an analogy for it, or (e) build a mental or physical model of it. In other words, the students have made the concept their own. This is what we call conceptual understanding (Konicek & Keeley, 2015). The question now is the conceptual understanding of the teacher because his misunderstanding shall translate into the conceptual misunderstanding of the student. The study commissioned by the European Commission (Michel R. et al, 2007) observed that

"Despite the numerous projects and actions that are being implemented to reverse …the trend of an alarming decline in young people"s interest for key science studies and mathematics, the signs of improvement are still modest. Unless more effective action is taken, Europe"s longer term capacity to innovate, and the quality of its research will also decline". The study then poses the old rhetorical question "What is meant by Science?" It then proceed to define science in the modest form: "Science, in the broadest sense, refers to any system of knowledge which attempts to model objective reality. In a more restricted sense, science refers to a system of acquiring knowledge based on the scientific method, as well as to the organized body of knowledge gained through such research."

According to the method of science (Moyer *et al.*, 2002); the science process skills include observation, inference to form an idea from observations, classification by putting together things that share properties, measure to find size, distance, time, volume, area, mass, weight, or temperature; use numbers to order, count, add, subtract, multiply and divide to explain data; predict possible results of an experiment, form hypotheses that can be tested to answer the question(s), use variables to identify things in an experiment that can be changed or controlled, experiment to perform a test to support or disapprove a hypothesis, make a model to represent the object or event, define terms based on observations to put together a description that is based on observation and experience.

The poor academic performance in mathematics and science is an area of concern to the developed as well as developing countries. The United States (Holdren *et al.*, 2010), Ireland (Horn, 2010) and Jamaica (MOEYC, 2003) among others, have expressed in their policy reports that the performance of science and mathematics is poor and needs to be addressed for the improvement of their human resource. The United States has put it even more emphatically that she needs to improve Science, Technology, Engineering and Mathematics (STEM) performance for the 21st Century competitiveness calling STEM the engine of economic growth.

In Uganda, although mathematics has been made compulsory, it is one of the most poorly done subjects which affects enrolment into science courses. Uganda National Academy of Sciences put the tertiary institutions gross enrolment ratio of science at 1.15% which it said is too low to support industrial growth (UNAS, 2010). The perpetual poor performance of science and mathematics makes the teacher conceptual understanding an important candidate for research.

The government measures are appropriately focusing on science driven skilled labour but affected by poor science academic performance at secondary school level which feeds students into tertiary institutions. This research sought to establish the reasons why this continue to be so in spite of the many studies conducted to guide policy on solving the problem of poor science and mathematics academic performance. The review of the research so far undertaken indicate that it has largely dwelt in other areas apart from the conceptual understanding of science and mathematics by the teachers. The studies on the conceptual understanding have mainly patronizingly focused on students while grouping the cause of poor teaching to lack of qualified teachers. The research so far carried out is generally characterized by the findings of the following authors.

Aina and Akintunde (2013) analyzed gender in physics performance and concluded that there is no gender bias although male students were better in performance than female students. Aina and Adedo (2013) found the causes for low enrolment in science to be lack of qualified science teachers, lack of instructional materials, subject nature, low student interest and lack of motivation. Specifically, the generalization of lack of qualified science teachers may not explain why the produced scientists have lacked innovativeness and practical application of scientific knowledge since colonial times in Uganda. The instructors of teachers may be the problem or the instructors of the instructors which could lead us into a chain of disclaimers of responsibility for the student poor science and mathematics academic performance.

The study by Olorundare (2011) observes that "over the last two decades there are reflections across nations that teaching and learning of science is problematic at the secondary school level and that efforts made so far to improve the teaching and learning of science in secondary schools across the globe have not yielded the much needed results and therefore deserves further attention". The study reviews correlates of students" poor performance covering sociopsychological variables: locus of control, self-efficacy, interest in schooling, self-concept, selfesteem, self-confidence, self-regulation, study habits among others. The others include influence on teaching strategies, content knowledge, motivation, laboratory use and non-completion of the science curriculum in a year. The solving of the content knowledge through teacher training may compound the problem of rote teaching without solving the problem of teaching for conceptual understanding. This is why it is necessary to isolate the teacher conceptual understanding in conjunction with student conceptual understanding.

The study examines the use of outdated teaching practices and instructional methods, the indirect influences such as: roles played by parents in their children"s education; general competencies and use of language in understanding scientific concepts; the lack of basic content knowledge which result in poor teaching standards and consequently student"s poor performance. The paper mentions "general competencies and use of language in understanding scientific concepts" without further elaboration on this aspect which should have been considered as paramount for the demystifying of the teaching of science and mathematics. The conceptual and perceptual issues of science and mathematics have also been widely explored by (Khata & Krissana, 2011; Kleanthous & Williams, 2010; Michael & Paul, 2007; Wright & Chorin, 1999) generally lacking treatise on the teacher conceptual understanding of science and mathematics.

The study adds that, "while every situation in every community, nation or educational system may be different there is no doubt that teachers as well as parents/ guardians have a great responsibility to help student succeed and that the student should be assisted to hold and positively discharge the most responsibility"; and that "teachers" performance in every parameter has a significant impact on students" understanding and performance". The paper observes that "the Nigerian curriculum is highly scripted" and that this no doubt leads to less teacher autonomy and argues that less scripted curriculum causes a stronger link between teacher skill and student achievement; that the curriculum is often overloaded and that teachers make every effort to „rush" completion of the syllabus.

The study also elaborates on the overcrowded classrooms as usually disabling attention to individual student"s needs and challenges and closes with ethnicity and gender issues as other causes of poor science performance.

Maria, Vera and Francisco (2012) conducted a study to determine how different but interrelated variables could lead to an explanation of student attitudes towards math. Oksana, Alves and Bahry (2012) investigated students" career awareness in Science and according to the results…it was discovered that for both the USA and Canada, students" self–efficacy in science had the largest direct effect on their science proficiency. In their analysis, Minkee and Jinwoong"s (2010) findings revealed that students" intrinsic attitude to science stimulates their school achievement. In particular, subject–related enjoyment and interest have been found to have positive effects on performance outcomes (Lepper & Cordova, 1992 cited by Oksana *et al.,* 2012). Singh, Granville, and Dika (2002) found out that high achievement in mathematics is a function of many interrelated variables related to students, families, and schools. In addition, Mato and De La Torre (2010 quoted by Maria et al 2012) discovered that students with better academic performance have more positive attitudes regarding math than those with poorer academic performance.

The author having realized that previous studies concentrated on lack of teaching materials, the negative attitude of students, the socio-economic environment and the poor training and motivation of teachers, as the reason behind poor academic performance in general, he proceeded to establish the teacher conceptual status of science by asking them the simple question of "what is science?" The study also proceeded with a hypothetical understanding that it is probably difficult to understand science without a good knowledge of mathematics. This hypothetical understanding led the author to carry out research to establish the teacher conceptual status of mathematics by asking them a simple question of "what is mathematics?"

2.1 Sample selection

The research covered schools around Kampala district which have relatively better facilities with regard to accessibility, infrastructure, teacher availability, science laboratory and mathematics equipment, and information technology. This enabled the research to get a homogeneous sample to deal with the research questions. The study covered both primary and secondary schools around Kampala which were deemed to have teaching materials and whose teachers were graduates and owned cars. The schools had science laboratories and facilities of a standard Uganda school and their location around Kampala, the capital city of Uganda ensured that they had electric power for light, water and sanitation facilities in addition to being accessible due to the better urban infrastructure. The study used these parameters for teacher quality, good pay and motivation. This characterization of the sample was deemed the best for the study since it allays lack of motivation and teaching skills given that the capital attracts the best teachers, distance from school, lack of infrastructure, lack of science laboratory and equipment. The following method was used to establish the teacher conceptual understanding of science and mathematics.

3.0 Methodology

The use of grounded theory method was found appropriate for this study (Janice *et al.*, 2009). Although it is not perceivable that any researcher can enter the field without conceived value judgment as a consequence of his education and social setting, the use of grounded theory seeks to generate conceptual understanding of science from the respondents with the restraint of imposing personal views and judgment. A questionnaire was administered to cover a sample of 100 teachers. Descriptive statistics was used to determine the weights of the responses which were tabulated. Workshops were carried out amongst the respondents for consensus on the generated conceptual understanding of science and mathematics. Triangulation was used to help generate the practical conceptual understanding of science and mathematics from the collected answers (Wendy, 2004).After the above process, the resultant conceptual understanding of science was juxtaposed against the Moyer (2002) science process and the dialectical method (Patrick, 2001, pp. 509) in the philosophy of the theory and practice of knowledge and found to be in agreement across the board with the scientific method.

4.0 Research findings

Table 1: Tabulation of the response to the question; what is science?

#	Answer	Ratio
1	Study of living and non-living things	65/95
2	A discipline with high base of cognitive, psychomotor, and practical skills	1/95
3	Application of theories, principles and concepts to explain phenomenon apply it	1/95
4	Study of investigation and inquiry	1/95
5	Study of knowledge in systematic arrangement showing operational laws	1/95
6	Study of matter	1/95
7	Study of how things work	2/95
8	Study of forces	1/95

9	Study of man, nature, environment, structure, behavior, with experimentation	14/95
10	Study based on seeing, testing and proving of facts practically	5/95
11	Study of natural science (nature) and social science (man and society)	3/95
	Total Respondents	95/95

Table 2: Tabulation of the response to the question; what is mathematics?

#	Answer	Ratio
1	Abstract science of numbers, quantity, quality and space	8/95
2	Examining and proving numbers and shapes	1/95
3	Science subject dealing with manipulation of numbers	3/95
4	Subject dealing with numbers, structures, shapes and space	5/95
5	Group of sciences using symbols, with logic of quantity, shape and arrangement	1/95
6	A branch of science dealing with numerals and even letters	2/95
7	A way of solving problems	1/95
8	Ways of calculating numbers	6/95
9	Application of numbers and symbols to give a meaningful statement	1/95
10	Study of operations of numbers and mathematical symbols in systematic manner	9/95
11	Calculation of nature in the environment using the nine digits	1/95
12	Science of dealing with operations of figures and word problems	2/95
13	Means of playing with numbers basing on the given instruction	1/95
14	Study of different values of items in terms of measurement and shapes	2/95

15 Science of using symbols, signs, formula, and figures to arrive at conclusions 3/95

16 Art of counting numbers 3/95

17 Science of numbers, figures, symbols and shapes 7/95

18 Deals with numbers, symbols and get meaning out of them/ solve problems 4/95 19 Art of analyzing issues critically 1/95

20 Study of number ideas, concepts, space measures and theorems 4/95

21 Science of numbers, quantities, shapes, geometric in comparison 4/95

22 Art of assessing, analyzing and interpreting facts in numerical form ready for use 1/95

23 Subject that deals with calculations and solving unknown numbers 1/95

24 Study that involves "numeracy" that require practical skills 1/95

25 Science of operationalizing numbers 2/95

26 Language of science that proves its theories 5/95

27 Study of methods of calculation, numerals and their application 2/95

28 Study of skills used to count and measure quantities in our daily lives 1/95

29 Study of qualitative and quantitative plans, shapes and sizes 2/95

30 Mathematics is applied science which deals with figures and measurement 2/95

31 Science involved with knowledge and skills of handling numerical of daily life 2/95

32 Science of numbers, quantity, space and measurement 2/95

33 Application of figures, numbers and words to solve scientific problems 2/95

34 Science of logic 1/95

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35	No answer	2/95
Total response		95/95

4.1 Analysis of Results

The respondents to the two questions try to define what science and mathematics are. The answers are logically aligned differently. There is a general lack from the gathered responses to describe science and mathematics from the perspective of what they do in life. There appears therefore to be a general conceptual problem of science and mathematics. If we have a conceptual problem, then we have an application problem. It is not possible to practically teach science and mathematics if conceptually science and mathematics are not perceived as practical tools. There is need to develop a practical conceptualization of science and mathematics since the question of life and living are indeed practical questions. The practical conceptualization of science needs to be grounded in the pedagogy of mathematics and science subjects to promote student conceptual learning.

Key words in the concept of Science from the respondents:

Study Living Non-living Cognitive Psychomotor Practical Theories Principles
Concepts to explain phenomenon Investigation Inquiry Systematic arrangement
Study of matter Study of forces Study of man Study of environment, structure, behavior
Experimentation Testing Proving

Distillation of the description of science from the table:

Science studies man and nature and undertakes systematic inquiry and test of their behavior and the structural transformation of nature and thereby builds theories, concepts and principles

Key words in the concept of Mathematics from the respondents:

Abstract science of numbers	Applied science	Numerical	Measurement	Science of logic
Calculation symbols	Solving problems	Proving numbers	Manipulation of numbers	
Playing with numbers basing on the given instruction	language of science			
Application of figures, numbers and words to solve scientific problems				
Science of numbers, quantity, space and measurement				
Study of qualitative and quantitative plans, shapes and sizes				
Mathematics is applied science which deals with figures and measurement				

Distillation of the description of mathematics from the table

Mathematics is a logical language of science which uses numbers and symbols to measure space, shapes, sizes, movement, direction and processes to arrive at scientific proofs and conclusions

Combining the two definitions:

Science uses mathematics as a logical language in the study of man and nature through systematic inquiry and test of their behavior with the aim of applying the derived knowledge for the transformation of life and the environment.

There were also other findings of the survey on other incidental issues which are recorded below:

Perception of teaching and attitude to mathematics performance

Table 3: Statement: The cause of poor mathematics performance is due to poor teaching

#	Answer	Ratio

1	Agree	65/95
2	Disagree	25/95
3	Don‟t know	5/95
	Total	95/95

The results indicate that majority of teachers (68%) put the blame for poor mathematics performance on poor teaching which they observe is a result of; intangible teaching, poor communication, lack of mathematical knowledge and teaching skills, arrogance and harshness of teachers to students. The smaller percentage (26%) put the blame on the poor attitude of students, lack of motivation for teachers, lack of teaching materials and class size. The problem of the big class size is however addressed in some schools by increasing the number of mathematics teachers per student.

Table 4: Statement: The cause of poor teaching is due to the curriculum content and load

#	Answer	Ratio
1	Agree	45/95
2	Disagree	41/95
3	Don‟t know	9/95
	Total	95/95

The results indicate that there is almost a balanced reaction on the cause of poor performance being due to the curriculum content and load. Forty-seven percent of teachers (47%) agreed that the curriculum has problems ranging from repetition of concepts, duplication of content and being too loaded and does not allow teachers to give enough time to concept building and demonstration due to rushing to finish the syllabus. Forty-three percent (43%) disagreed that the cause of poor teaching is due to the curriculum content and load. They put the causes on other factors like the poor attitude of students, lack of motivation for teachers, lack of teaching materials and class size.

5.0 Policy recommendations:

- The demystification of science and mathematics for holistic abilities of all teachers to teach life-skills
- The need to carry out research and to develop locally relevant educational materials and books
- The teachers‟ need for refresher and short-courses in science, mathematics and the holistic approach
- The urgent need to train teachers for a holistic conceptual understanding of the theory and practice of science and mathematics for economic growth

5.1 Areas for Further Research:

Approaches and materials that promote the conceptual understanding of science and mathematics for the teaching of science.

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