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Comparing the Effectiveness of an Inquiry-Based Approach and Traditional Method of Teaching in the Conceptual Understanding of Genetics to High School Students of Morogoro-Tanzania

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Abstract:
Current perspectives on science education as well as the current curriculum policy in Tanzania stresses on the use of teaching methods that promote active engagement of learners during teaching and learning processes such the inquiry based approach. This study aimed at assessing the effectiveness of an inquiry-based approach on students' conceptual understanding of genetics by comparing it with traditional or conventional style of teaching. The study used genetic as the case study to find out whether or not these two styles of teaching genetics would develop differently students' science process skills. Inquiry-based approaches to science have been heavily emphasized by the newly adopted competence based curriculum in Tanzania. Two months (08weeks) were spent during the summer of 2015 in teaching themes within genetics at the selected schools in the vicinity of Morogoro Municipality. The study employed a quasi-experimental research design with pre and posttests. Eight (08) weeks genetics teaching courses were designed on the basis of both the inquiry based learning principles and conventional style. A genetics test of 25 items was used as a data collection tool in the pretest and posttest. Form six classes were taught using conventional method while form five classes in these schools had enough time and were taught using inquiry approach. Both classes had never been exposed to advanced level genetics. Independent samples t-test for experimental group (M = 21.73. s.d = 1.67) and that of control group (M = 21.87, s.d = 1.93), t (261) = 0.606, ρ = 0.545, α = 0.05. Hence, the null hypothesis, that there is no statistically significant difference in genetics posttest scores between the control and the experimental groups was accepted at 0.05 alpha levels. This means that there were no statistically significant difference in the effectiveness of inquiry-based (IBA) approach and the conventional method (TM) in enhancing the conceptual understanding of genetics content to students.

1. Background and Problem Statement

1.1. Background and Context of the Study

In the early 2000s, Tanzania began a process of curriculum reform with the goal of transforming Tanzania schooling from exam-oriented education to student centered learning. Traditional education practices had expected students to passively accept and memorize material presented by teachers, and to reproduce the knowledge on often high-stakes examinations. As a result of these transformations, in 2005 Tanzania came up with the so called 'Competence Based Curriculum' which emphasized among other things, students' competence in science process skills. The curriculum emphasized the need of Tanzania science students to learn science subjects such as Biology, Physics and Chemistry in the same way science is done scientists. The new syllabus adopts a two-fold approach of developing students' process skills while testing their content knowledge (URT, 2005). Statements such as students should be able to compare, classify, use apparatus and equipment, communicate, infer, formulate hypotheses, make prediction, analyze data, define variables operationally are very much seen in the new curriculum (URT, 2005). These skills are known as scientific process skills and are essential tools for students to explore and acquire scientific knowledge within and outside the classroom (Chiapetta and Koballa, 2002).

This curriculum was reviewed in the spirit of constructivism to enhance participatory and inquiry approaches to teaching (Tilya&Mafumiko, 2008). The curriculum emphasized the need of Tanzania science students to learn scientific subjects such as Biology, Physics and Chemistry in the same way as how science is done by scientists. The curriculum further emphasizes the use of inquiry based approach to be an integral part of science teaching. With constructivism philosophy, learners are encouraged to participate actively in the lesson, use their pre-concept knowledge, and engage in classroom activities so as to construct meaning out of the lesson (Kelly, 1991). The new curriculum policy acknowledges the fact that, inquiry-based teaching approach must be an integral part of science education if science process skills are to be acquired by students. In the advanced level Biology syllabus of Tanzania of 2010 for example it is stated that… …

….. Teachers are advised to use participatory teaching and learning strategies as much as possible to help learners demonstrate self-esteem confidence and assertiveness (Pg.vii).

As one of the participatory methods of teaching, the inquiry-based approach requires teachers to facilitate the inquiry process, granting student responsibilities for their learning while modeling and scaffolding the cognitive and investigative processes involved (Lebow, 1993; Myer, 2004; Kirschner et al. 2006). The approach provides opportunities to understand the scientific inquiry process and to develop general investigative abilities (such as posing and pursuing open-ended questions, synthesizing information, planning and conducting experiments and analyzing and presenting results), as well as to gain deeper and broader science content knowledge that has real-world application (Prawat, &Floden, 1994). The skills are collectively called Science Process skills. In the teaching of science through inquiry approach, teachers act as facilitators, motivators and inspires for students in driving the lesson. This is in contrast to a traditional paradigm where teacher´s role is to decide, control and direct student learning in what is known as banking education (Barakatas, 2005). The teacher is an authority who decides what and how their students should be teaching (Chung, 2004). Lessons are designed with a view to specific learning outcomes which are outlined in structured lesson plans. Evaluation of learning is based on student performance on objective tests (Floresc&Kaylor, 2007).

1.2. Genetics and the Competence based Curriculum-Tanzania

Conceptual understanding of genetics is one of the key issues addressed by the competence-based curriculum of 2005 in Tanzania. Genetics is concerned with genes, heredity, and variation in living organisms. It seeks to understand the process of trait inheritance from parents to offspring, including the molecular structure and function of genes, gene behavior in the context of a cell or organism (e.g. dominance and epigenetics), gene distribution, and variation and change in populations. The topic forms one of the central core contents of advanced level Biology contents. Genetics is defined by Jennings (2004) as a field of study that is concerned with heredity and how particular qualities or traits are passed on from parents to offspring. The term genetics literacy was proposed as a part of scientific literacy to emphasize the issues and challenges that are related to genetics and biotechnology (Jennings, 2004; Freidenreich et al. 2011). Genetics literacy provides sufficient knowledge and appreciation of genetics principles to allow informed decision-making and for personal well-being and effective participation in social decisions on genetics issues (Bowling et al. 2008). According to the advanced level Biology syllabus of Tanzania (2010), genetic contents are categorized into the following subtopics i. Hereditary materials (DNA/RNA), ii. Genetic coding and protein synthesis, iii. Mendelian inheritance and pedigree, iv. NonMendelian inheritance v. Sex linked inheritance and vi. Gene and chromosomal mutation.

Over the last several decades, the role of genetic technologies in health and public policy has persistently increased (Miller, 1998) and new knowledge in genetics continues to have significant implications for individuals and society (Tsui and Treagus, 2010; Lewis &Kattman, 2004). Rapid advancements in genetics and genetic technology are creating opportunities for the understanding, prevention, treatment and cure of human diseases. Tsui and Treagust (2010) stressed the importance of having contemporary knowledge on DNA, genes, and their relations to human affairs on making informed decisions about ethically and socially controversial issues. Genetic issues now play a large role in health and public policy (Miller 1998 &Freidenreich et al. 2011). Competence in genetics is necessary not only to make thoroughly informed decisions about socio-scientific issues such as cloning, genetic screening, gene therapy and genetically modified foods but also their ethical, legal, and social implications (Bowling, 2007). Poor genetic literacy for example in Tanzania has led to the brutal murder and attacks on innocent men, women, and especially children with albinism under the influence of witchcraft and superstition and desperation for wealth. These misconceptions, coupled with the lack of education are some of the key reasons that albinism is so heavily persecuted. Enhancing students´ understanding of genetics can improve communication regarding genetic information and technologies, and help to ensure its appropriate use (Tsui & Treagus, 2010; Lewis &Kattman, 2004).

1.3. Aim of the Study

The main purpose of this study was to compare the effectiveness of an inquiry-based approach and traditional method of teaching in the conceptual understanding of genetics to high school students. Morogoro Biology students in Tanzania were taken as a case study

1.4. Problem Statement

It is twelve years now since the inception of the competence-based curriculum in Tanzania. The newly revised competence based curriculum of 2005 has placed a heavy emphasis on the need for secondary school science teachers to move from traditional ways of teaching to more of constructivist approaches like inquiry based approach. The new curriculum emphasized the need for science students to learn scientific subjects in the same way science is done scientists. The curriculum encourages science teachers to use participatory inquiry-based approaches as much as possible. There is no clear evidence as whether or not learners who are being taught using inquiry participatory approaches are acquiring doing comparatively different from those who are traditionally taught. Hence it became vital for this study to develop genetics lesson modules based on inquiry teaching and learning principles, implement to students and measure its effectiveness in the conceptual understanding of genetics of students as compared to the conventional approaches. Despite numerous studies on the value of inquiry teaching approach worldwide and its acknowledgment in the Tanzania syllabuses, review of literature and studies failed to identify any study that scientifically investigated the effectiveness of the approach on students' scientific process skills development. Genetics has been chosen as a focus point in this study because it is a topic that offers a lot of opportunities where students can practice realistic problem solving. Genetics is one of those topics that are relevant to our daily lives. Understanding how genetics plays a role in our past, present and future helps us to better understand ourselves and those around us. Available studies reported that genetics is among the main topics that students struggle with serious conceptual difficulties (Duncan &Reiser, 2007; Jennings, 2004; Lewis &Kattman, 2004) therefore genetics topic is crucial to be selected as a case study in assessing which one is the effective instructional method between conventional methods or an inquiry-based approach to science. Although the problem-solving skills gained in genetics relate to a specific domain of learning, one hopes the skills gained in learning how to approach problem-solving in genetics would be transferable to other areas of life.

2. Methods

2.1. Research Design

Quasi-experimental design involving experimental and control groups was employed in this study. This is because secondary school classes exist as intact groups and school authorities do not normally allow classes to be dismantled and reconstituted for research purposes (Shadish, et al. 2002 &Njoroge et al, 2014). Hence there was a non-random assignment of students to the groups. Quasi-experimental researches are widely used in the evaluation of teaching interventions because it is not practical to justify assigning students to experimental and control groups by random assignment (Randolph, 2008 &Njoroge et al, 2014). Quasi-experimental research offers the benefit of comparison between groups because of the naturally occurring treatment groups (Cohen et al. 2007). In this study, the experimental groups were exposed to the treatment (inquiry-based approach) and the control groups received no treatment (they were taught using traditional methods only). For both the pretest and posttest, Biology process skill test (BPST) was used a data collection tool. The performances of the two groups were then compared to determine whether there are any treatment effects as a result of different teaching styles on the same contents.

2.2. Data Collection Tool (Genetics Tests)

To assess genetics knowledge as a covariate, a multiple-choice (single-select) item test containing 25 items was developed. A number of sources were reviewed for possible test items, including the example questions provided by the College Board's Advanced Placement Biology Exam, the SAT II Biology Exam, and the Biological Science Curriculum. Suitable items were ultimately included in a pool of questions. The test measures five (05) subtopics in Genetics as listed in the Tanzania Biology syllabus for the advanced level students which include i. hereditary materials (DNA/RNA), ii. genetic coding and protein synthesis, iii. Mendelian and Non-mendelian inheritance, v. sex-linked inheritance and pedigree analysis, and v. gene and chromosomal mutation. The test was reviewed by the supervisor of this study who is a professor of zoology and didactics of Biology to assure its content validity. A panel of three science educators further determined the content validity and clarity of each item on the test. The science teachers also analyzed the relatedness of the test items to the instructional objectives. They confirmed that the content validity of the instrument was appropriate for the participants. However, psychometric validation of this conceptual test was beyond the scope of this study. For scoring purposes, each multiple-choice item was given a numeric value of 1 if the response was correct or 0 if the response was incorrect. Therefore, scores ranged from 0 to 25.

2.3. The Rationale of using Genetics Topic as a Case Study

Genetics is one of the central topics addressed by the competence-based curriculum of 2005 in Tanzania for the Advanced level Biology students. Genetics was taken as a case study because the topic is considered one of the most important and difficult topics in the school science curriculum (Tsui & Treagust, 2010). A number of reasons as why genetics concepts are difficult for students to learn have been reported by both teachers and researchers. For example, Pinar &Ceren (2008) indicated that these difficulties originate mainly from the domain-specific vocabulary and terminology, the mathematical content of Mendelian genetics, the cytological processes, the complex nature of genetics, and the abstract nature of the subject matter. According to Lewis & Wood-Robinson (2000), various genetics concepts depend on imaginary (theoretical) ideas constructed in abstract hypothetico-deductive conceptual systems. Therefore, a sound understanding of theoretical genetics concepts requires learners to reason hypothetico- deductively. Likewise, Banet and Ayuso (2000) argued that meaningful understanding of genetics is difficult and requires a certain level of abstract thought. Tsui and Treagust (2010) stressed the importance of having contemporary knowledge on DNA, genes and their relations to human affairs on making informed decisions about ethically and socially controversial issues. Researchers in science education have consistently criticized the traditional teaching approach and suggested the development of more effective alternatives such as the inquiry-based approach.

2.4. Participants in the Study

The participants of the study were 263 advanced level Biology students from selected secondary schools in Morogoro Tanzania. Three schools namely Kilakala (145 students), Alfagerms (87 students) and Bigwa sisters (31 students) were involved in the study. Activities that used inquiry, hands-on models and problem-solving were targeted to form five students while a lecture method was employed to teach form six students. This is because of the fact that Form six students didn't have much time for inquiry activities. These are finalist students and always busy for the preparation of their final national examination. The students, divided into an experimental (169 students) and a control group (94 students), attended a biology course that involved themes on modern genetics and Mendelian inheritance topics. As summarized in table 6.1 below, the number of female students involved was 200 (130 in inquiry classes and 70 in conventional lecture method) while there were 63 male students 24 being in conventional lecture approach and 39 were involved in inquiry classes. The emphasis was on the understanding of the nature, function and correlations between the basic genetic concepts (e.g. DNA, genes, chromosomes, and meiosis) and the phenomenon of Mendelian inheritance protein synthesis and Mutation. None of the participants had been taught genetics at higher levels in the past.

			Sex		Total
			Female	Male	
Kilakala sec school	Type of instruction	Conventional approach	49		49
		Inquiry based method	96		96
			145		**145**
Alfagerms	Type of instruction	Conventional approach	7	24	31
		Inquiry based method	17	39	56
			24	**63**	**87**
Bigwa Sisters	Type of instruction	Conventional approach	14		14
		Inquiry based method	17		17
			31		**31**
	Grand total		**200**	**63**	**263**

Table 1: Distribution of students by type of instruction and sex in each school
Source: Research survey (2014)

2.5. Controlling Teacher Factors/Variables

Review of research literature has led to the conclusion that it is the teacher, more than the material, the method, or any other variable, that makes the greatest difference in children's educational achievement (Wright, et al., 1997 & Hattie 2009). Teacher factors such as self- efficacy, interest, attitude, qualification, motivation, experience, knowledge, skills, teaching competence cannot be ignored as can have profound impacts on various students' learning outcomes (Wang, et al., 1993). At the heart of this line of inquiry is the core belief that teachers make a difference. For instance, teachers who demonstrate patience, knowledge of intervention techniques, an ability to collaborate with an interdisciplinary team, and a positive attitude towards children can have a positive impact on student learning success and the vice versa is true. In order to control the influence of teacher variables in this study, both the control and experimental groups were taught themes of genetics by the researcher only who is also a Biology teacher. The researcher taught genetics to the control group using conventional lecture method and the experimental group using inquiry-based approach. This means that differences in students' performance if there are any, can directly be attributed to the effectiveness of the method of teaching rather than the influence of teacher variables.

2.6. Implementation of Genetics Lessons to the Control Group

Conventional method was employed to teach themes within genetics to form six student classes in the selected schools. Lecture notes and discussion questions were prepared in advance before the actual class session. Three different textbooks prescribed by the Tanzania Biology syllabus and proved adequate to provide the essential factual basis for the course and were used in the construction of student's notes and discussion questions. They included Biological Sciences by D.J. Taylor, Understanding Biology for Advanced Level by Glenn Toole and Susan Toole and Advanced Biology Principles and Applications by D.J Mackean. Each subunit met a total of 240 min/week (either 80 min on Monday/Wednesday/Friday or 120 min on Tuesday/Thursday) plus a 50-min recitation each week for a total of 8 weeks. Topics discussed included i. Hereditary materials (DNA/RNA), ii. Genetic coding and protein synthesis, iii. Mendelian genetics iv. Non-mendelian inheritance and pedigree analysis, v. Gene and chromosomal mutation vi. Meiotic and mitotic chromosome behavior, including recombination, mapping, and chromosome aberrations. Posttest scores of students were reported back to their respective Biology teachers at the end of intervention so that remedial measures could be taken for those who didn't perform well. Student marks were also supposed to be included in their total coursework results.

2.7. Implementation of Genetics Lessons to the Experimental Group

Activities that used inquiry, hands-on models and problem-solving were targeted for form five students in the selected schools. The 5E instructional model (Bybee, et al, 2006) and constructivism theory formed guided teaching in the experimental group. The role of the researcher in the experimental group was to promote discussion, active learning and provide modeling, coaching and scaffolding to students when required. As suggested by constructivists, the teacher (the researcher) acted as a facilitator rather than the custodian of knowledge. Many hours were dedicated in building new activities/models, and other activities. Throughout the teaching, Biology students were working in small groups where they were encouraged to explore problems, formulate hypotheses, designing micro experiments share their ideas with their classmates, discuss their observations and interpret findings of the experiments or hands-on activity carried out. For example, students investigated some inherited and acquired human traits that are easy to observe in a classroom. Working in groups of four, students took a personal inventory of their traits (i.e. dimples, widow's peak, pierced ears, etc) and compare their traits to the rest of the class. In addition to introducing basic genetic terminology, this activity introduced the concepts such as the relationship between molecular differences in the DNA and observed physical traits and the difference between inherited and acquired traits. Students also had the opportunity to practice inquiry skills, make data tables, and analyze graphs.

The students' main learning aid was a set of worksheets which was collected from different sources mainly websites (see table 2 below) prepared specifically for the teaching of the genetics. The worksheets complete with short articles as a source of new information, tables, diagrams, pictures, exercises, and guidelines for small investigations, facilitated the application of the inquiry approach. Several small changes had to be made as the teaching progressed to adjust to the specific needs of the students and to support their investigations. At the beginning of some lessons, students were presented with a scientific phenomenon or set of data and were asked to make observations and specify relevant research questions after selecting an appropriate problem for investigation. The experimental group underwent a total of sixteen inquiry-based lessons, of which two lessons on average were accomplished per week in eight weeks as shown in table 2 below.

Day	Activity	Hands-on Models (M) Problem Solving (PS) Inquiry (I)
Day 1	Pre-test	BPST test
Week 1	Chromosomes structure, Mitosis and meiosis	Discussion on Chromosomes structure and functions
		Mitosis hands on activity
		Meiosis Model Activity
Week 2	DNA as a hereditary material	Extracting DNA from Your Cells
		DNA replication: A case discussion of a landmark paper by Meselson and Stahl
Week 3	RNA and Protein synthesis	Protein Synthesis Modeling activity
		A case discussion of protein synthesis questions
Week 4	Mendelian Genetics	A class discussion of Mendel's pea plants experiment
		Modeling monohybrid crosses activity
		Dihybrid Cross Activity (Busch Gardens, 2003) Problem Solving Activity
Week 5	Non Mendelian Genetics	Sponge Bob Incomplete Dominance Activity
		Using Blood Types to Solve a Mystery Class Activity
Week 6	Sex linked and pedigree analysis	Sex determination discussion activity
		Sex linked characteristics and the royal family pedigree problem solving activity
Week 7	Blood genetics and Lethal genes	Personal pedigree and analysis survey activity by Larry Flammer (2006)
		Blood Typing Murder Mystery Activity
Week 8	Gene and chromosomal mutations	DNA Mutations- Become a Genetic Counselor
		Mutation inquiry activity questions
Final day	Post-test	BPST test

Table 2: Sequence of Activities. This table includes all activities addressed during the genetics unit and their category as a hands-on model, problem solving, or inquiry-based activity

2.8. Administration of Test

The test was administered at the beginning (pretest) and at the end of genetics course intervention (posttest) to ensure that all subjects have undergone approximately the same science program. To minimize disruption of teaching in the classes involved, the genetics test was administered on the first day of intervention. The tests were administered in the same week in order to minimize the effect of learning that would have occurred in between the administration of the tests. The test was supposed to be completed within thirty five (35) minutes only. There were no data losses because schools involved were boarding schools at which all of the students live during the part of the year that they go to lessons. So it was easy to control their class attendance.

2.9. Data Analysis Plan

Genetics test provided quantitative data in terms of students score. These data were analyzed using SPSS version 21.0. The groups were given the pre-test and the post-test of science process skills. The overall pretest and posttest scores from the testwere calculated for each student in terms of the percentage of correct responses. These scores were analyzed in several ways. First, a general linear model was used to determine, whether there are statistical differences between the experimental and control groups in terms of their performance in the science process skills with time. A repeated measure analysis of variance was used to analyze the effect of time. It is the statistical measure used to examine multiple observations of scale overtime and/ or under different conditions (Schindler, 2014 & Green et al. 2000). In this study repeated measures analysis of variance (ANOVA) was conducted to test for between-group differences overtime. The measurement of time consists of time elapsed over 08 weeks of each aspect of study with measurement at pre-test (week 01) and post-test (week 08). Secondly, t-tests for paired samples were performed on the pre- to posttest difference scores (pretest scores subtracted from the posttest scores) for all participating students to test for statistically significant differences between pretest and posttest scores. A t-test was used to test differences between two means because of its superior quality in detecting differences between two means (Borg and Gall, 1996). All tests of significance were tested at a significance level of 0.05.

3. Result

3.1. Pretest Results from the Genetics Test

The aim of this quasi-experimental study was to compare the effectiveness of the inquiry-based approach and traditional method of teaching in the students' conceptual understanding of content. Genetics was chosen as a case study because the topic is essentially a problem-solving science and offers a fruitful area for studying student problem-solving performance. The genetics pre-test was administered to the experimental group and the control group in order to determine whether the two groups of students were similar in terms of their genetics knowledge level before teaching intervention. The test measured five (05) subtopics in genetics as listed in the Tanzania Biology syllabus of 2010 for the advanced level students. These subtopics included i. hereditary materials (DNA/RNA), ii. genetic coding and protein synthesis, iii. Mendelian and non-mendelian inheritance, iv. sex- linked inheritance and pedigree analysis, and v. gene and chromosomal mutation. Lack or absence of significant differences between students´ pretest performance of the two groups would infer that the cognate abilities of the groups were approximately the same prior to the intervention. At this point the study intended to determine whether or not there statistically significant difference in conceptual understanding of genetics between students which are expected to be exposed to an inquiry-based teaching (IBT) approach and those expected to receive the traditional method (TM).

The current study involved 94 (35.7%) control group students who were taught themes of genetics by using the conventional (direct instruction) method and 169 (64.3%) experimental group students who were taught using inquiry-based approach (IBA). Boone (1990) suggested that when conducting teaching methodological studies with teachers delivering the treatments, precautions need to be taken to ensure conformity to teaching the approaches under investigation. Hence to ensure conformity in teaching that would provide a realistic comparison, the same instructor taught all course subtopics in both the control and experimental group.

The mean scores and standard deviations of the two groups in pretest are shown in Table 3 (a). It is noted that the genetics test composed of 25 multiple choice questions and it was marked with one point per each question. Hence the maximum score a student could score was 25 out of 25. The results show that the mean of scores of the experimental group was 9.8 out of 25 genetics questions with the standard deviation of 2.88, while the mean of the control group 9.6 out of 25 items and the standard deviation of 2.77. The results of the mean scores on genetics test are also represented in a bar graph in Figure 6.3. Spread (standard deviation) of individual scores around their respective means was 2.88 for the experimental group and 2.77 for the control group. This means that before intervention variability the experimental group (2.88) was more than that of the control group (2.77) as shown by the coefficient of variation. This could imply that the experimental group was more homogenous than the control group before teaching intervention. Many students failed to connect genes to proteins and phenotypes, and as a consequence fail to recognize the importance of proteins in this process, thus in some cases students incorrectly assume that genes are particles that directly express traits in organisms. In both groups, student scores ranged from 06 to 14 out of 25 items present in the test. Figure 1 also summarizes pretest mean and standard deviation of the control group and experimental group students. Table. 3(a) Group statistics for genetics pretest scores of students based on the type of instruction (n=94 control group & n=169 experimental group)

	Grade Level of the Students	N	Mean	Std. Deviation
Grade level of the students	Inquiry Based Approach	169	9.8	2.88
	Conventional Method	94	9.6	2.77

Table 3: Group statistics for genetics pretest scores (n=263)
Source: Field data (2015).

An SPSS two-tailed independent samples t-test was conducted to test whether or not the observed pretest mean scores of experimental (IBA) and control (TM) classes on the genetics test are statistically significant or not. Table 3(a) indicates as if pretest performance of the experimental group as higher than that of the control group. However, no statistically significant difference was found between control and experimental group pretest mean scores on genetics test when the null hypothesis was subjected to the independent t-test. The null hypothesis stated that there is no statistically significant difference in the preconceptual understanding of genetics contents between those students to be exposed to inquiry-based approach and those to be exposed to traditional method (TM). An analysis of independent samples t-test based on genetics pretest mean scores of the experimental and control groups at alpha (α) =0.05 produced a p of 0.396 and a t value of 0.722. This means t-test failed to reject the null hypothesis at alpha (α) =0.05. Hence, the null hypothesis, that there is no statistically significant difference in the pre conceptual understanding of genetics contents between the control and the experimental group students was accepted at 0.05 alpha levels. Tables 3(b) summarize the independent samples pretest t-test of both the control and experimental groups.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Students pretest scores in Genetics	Equal variances assumed	0.722	0.396	-0.591	261	0.555	-0.213	0.361	-0.92	0.49
	Equal variances not assumed			-0.584	185.9	0.560	-0.213	0.366	-0.93	0.50

Table 3(b): Independent samples t-test for genetics pretest test scores
Source: Field data (2015)

The aim of administering genetics test before the actual intervention was to determine whether the experimental group and the control group were similar in terms of their pre-conceptual knowledge level genetics. These results from table 3(a and b) above suggest that the pre-conceptual knowledge level of the genetics of the control and experimental group students were comparable prior to the genetics course intervention. This means that the groups exhibited comparable characteristics in terms of genetics content knowledge before the actual genetics course. Lack or absence of significant differences between the pretest performances of the two groups infers that the cognate abilities of the groups were approximately the same prior to the intervention. It was then concluded that these groups of Morogoro Biology students were suitable for the intended comparative study.

3.2. General Linear Model Pretest Posttest Results Comparison for the Control and Experimental Groups

ANOVA for within - group differences (Test of within - subject effects) Within-person (or within-subject) effects represent the variability of a particular value for individuals in a sample. In this study, a repeated measure analysis of variance (ANOVAs) was conducted on genetics scores to compare for the within group differences overtime. Test of within - subject effects are an excellent measure to detect within-group differences over time. The intention was to test whether there is a significant mean gain score of the experimental and control group in genetics conceptual knowledge. In this test, the within subject factor was time with two levels (pretest in week 01 and posttest week in 08) and the dependent variables is the genetics scores at the pretest and posttest levels. Table 4(a) summarizes the findings of SPSS general linear model with repeated measure for pretest and posttest within- group effects with respect to genetics knowledge. A summarized in table 4 (a), the SPSS computation of general linear model with repeated measure for within -group effects (Sphericity Assumed) found F (1,261) = 4.328, p < 0.001, eta squared =0.943. Hence a significant main effect was noted for the time, F (1, 261) = 4.328, p < 0.001, which means regardless of the method of teaching there were a significant within groups effect on the conceptual understanding of genetics themes.

			Tests of Within-Subjects Effects				
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Test scores (Genetics)	Sphericity Assumed	17564.207	1	17564.207	4.328E3	0.000	0.943

Table 4(a): Within-subjects effects repeated measures ANOVA for two time periods (control group n= 94 & experimental group n= 169)
Source: Field data (2015)

This means that repeated measures analysis of variance rejected the null hypothesis that there is no statistically significant within-group effect in the conceptual understanding of genetics after teaching intervention over two testing occasions as a result of the methods of teaching. Eta square value was acquired as 0.943. This result shows that the effect magnitude is large and that almost 94.3% of the change in the dependent variable (genetic scores) results from the application. Student achievement increased in both groups as indicated by higher post-test scores. The experimental group increased their achievement but this was not statistically significantly different from the experimental group. This means Morogoro students learned the genetics content being taught in the same way regardless of teaching method and they perceived that student engagement was affected by the teaching method used.

ANOVA for between - subjects differences (Test of within - subject effects) in the Genetics test

A within subjects ANOVA was performed on genetics conceptual test scores to compare groups' scores over the two testing occasions. This multivariate repeated measures ANOVA was conducted with the factor being the two groups (control n= 94 and experimental group n= 169) overtime (pretest week and posttest week 8) and the dependent variable being student scores in the genetics conceptual test. The aim was to test statistically null hypothesis which stated that there is no statistically significant difference between control group students and experimental group students in the attainment of genetics knowledge over time. The general linear model for between- group interaction effects (method * groups* time) found F (1, 261) =0.924, p = 0.337. This means that the interaction was not significant at alpha = 0.5 and that the linear model accepted the null hypothesis. This means that there were significant gains over time and but there was no statistically significant differential improvement among the groups over time.

			Tests of Within-Subjects Effects				
Test and Type of instruction	Sphericity Assumed	3.750	1	3.750	0.924	0.337	0.004
Error(test)	Sphericity Assumed	1059.242	261	4,058			

Table 4 (b): Between-subjects effects repeated measures ANOVA for two time periods (control group n= 94 & experimental group n= 169)
Source: Field data (2015)

The statistical analysis revealed no significant difference in the performance of the two groups in the test, while both groups showed significant improvement (p<0.01) from the pre-test to the post-test. The findings in table 6.8 (b) implies further that regardless of the teaching method, there was an improvement of students genetics conceptual knowledge both, in the control and experimental groups. This means that both teaching methods (inquiry-based approach and conventional method) used in this study created a significant difference in advanced level high-school students' genetics disposition scores. Eta square value was acquired as 0.943. This result shows that the effect magnitude is large and that almost 94.3% of the change in the dependent variables (genetic scores) results from the application of the methods of teaching. The main findings showed that both methods had an impact on the development of genetics trend to students. These results, however, do not support anecdotal claims that the inquiry-based method of teaching is more effective than the traditional lecture method in enhancing the conceptual understanding of scientific concepts.

Posttest findings with the genetics test (Comparing the control and experimental groups)

Another purpose of this quasi-experimental study was to determine if there was a statistically significant difference in genetics achievement between experimental group students and the control group students. The overall aim here was to compare the effectiveness of the inquiry-based approach and conventional direct method in enabling conceptual understanding of Biology contents, with genetics being the case study. Student achievement was determined by the score comparison on 25 items multiple choice pre/post-test. Two independent-samples t-test was conducted to follow up the significant interaction and assess differences among teaching method groups at each time period. The hypothesis stated that there is no statistically significant difference in genetics achievement between students exposed to the inquiry-based mode of teaching (IBA) and those exposed to a traditional method (TM). The two groups were firstly given the pretest followed by a genetics intervention of 08 weeks before completing the same genetic test at posttest. The testing effects and influence of teacher variables across all the groups were nullified and the posttests of each of the experimental groups could be compared with that of the control groups to detect the effects of an intervention (see section 6.2.4). With the conventional method, lecture notes and discussion questions were prepared in advance before the actual class session. Three different textbooks prescribed by the Tanzania Biology syllabus and proved adequate to provide the essential factual basis for the course and were used in the construction of student's notes and discussion questions. They included Biological Sciences (1997) by D.J. Taylor, Understanding Biology for Advanced Level (1999) by Glenn Toole and Susan Toole, and Advanced Biology Principles and Applications by D.J Mackean and C.J Clegg. (2000) Each subunit met a total of 240 min/week (either 80 min on Monday/Wednesday/Friday or 120 min on Tuesday/Thursday) plus a 50-min recitation each week for a total of 8 weeks. In inquiry classes, many hours were dedicated to building new activities/models, and other activities. Throughout the teaching by inquiry, Biology students were working in small groups where they were encouraged to explore problems, formulate hypotheses, designing micro experiments share their ideas with their classmates, discuss their observations and interpret findings of the experiments or hands-on activity carried out. The school biology book was not used at all and the role of the teacher was reduced to that of a coordinator and facilitator of the students' work. The students' main learning aid was a set of worksheets which was collected from different sources mainly websites prepared specifically for the teaching of the genetics. The worksheets complete with short articles as a source of new information, tables, diagrams, pictures, exercises, and guidelines for small investigations, facilitated the application of the inquiry approach. Experimental group underwent a total of sixteen inquiry-based lessons, of which two lessons on average were accomplished per week in eight weeks as shown in table 2.

The posttest mean scores and standard deviations of the two groups on genetics test are shown in Table 5(a). The results of the mean scores on genetics are also represented also in a bar graph in Figure 6.3. The mean of students score in the experimental group was 21.73 out of 25 questions with the standard deviation (sd) of 1.67, while the mean of the control group 21.87 out of 25 items with the standard deviation (sd) of 1.93. This means that from pretest in week one, the spread (standard deviation) of individual scores in the control group decreased from 2.77 to 1.93 and also decreased from 2.88 to 1.67 for the experimental group students. Contrary to pretest results, the variability the control group was more than that of the experimental group as shown by the coefficient of variation (1.93 for the control group and 1.67 for the experimental group). Hence the at the end of teaching intervention, the control group, in this case, was found to be more variable than the experimental group in terms of their genetics knowledge than their counterpart experimental group students. This means inquiry-based and hands-on activities that the experimental group students underwent made their genetics knowledge level more homogenous than the control group at posttest. The findings that students in the experimental were relative homogenous as compared to the control group are in line with the claim put forward by Keys & Bryan (2001) who argued that authentic inquiry activities provide learners despite their cognitive abilities with the motivation to acquire new knowledge, a perspective for incorporating new knowledge into their existing knowledge, and an opportunity to apply their knowledge. Table 5(a) Group statistics for genetics posttest scores based on the type of instruction they received (n=263)

	Grade level of the students	N	Mean	Std. Deviation
Grade level of the students	Inquiry Based Approach	169	21.73	1.67
	Conventional Method	94	21.87	1.93

Table 5(a): Group statistics for genetics posttest scores based on the type of instruction they received (n=263)
Source: Field data (2015)

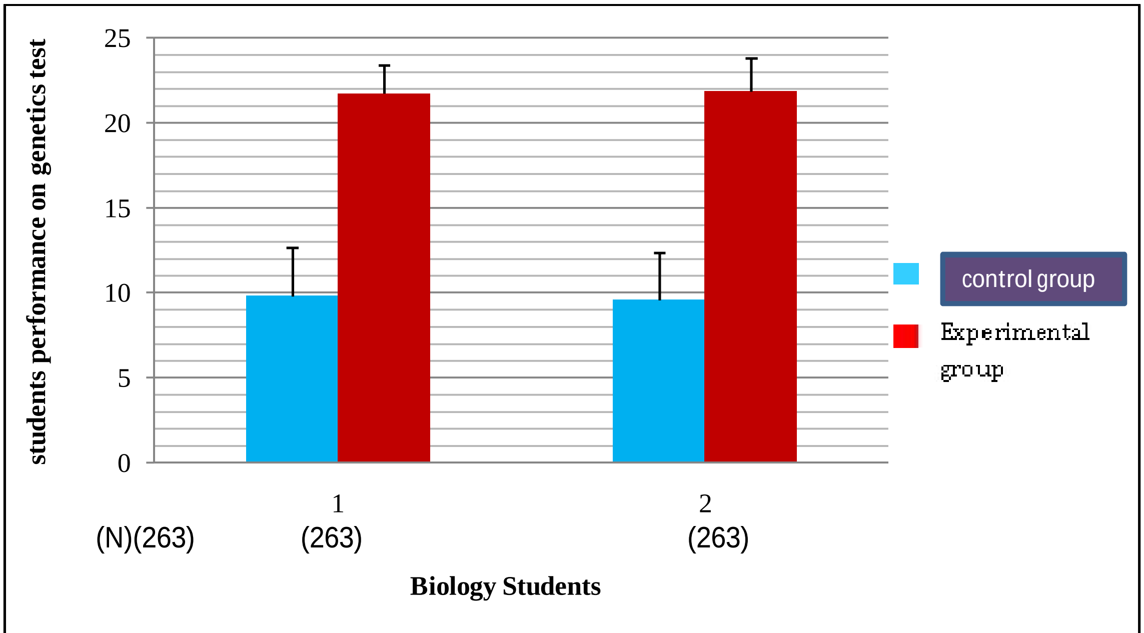

Figure 1: Mean and standard deviations of the control and experimental group in genetics scores

A two tailed independent-samples t-test was conducted to statistically compare the posttest means of experimental (IBA) and control (TM) classes on the genetics test. The aim was to test whether or not the mean scores were statistically significant or not. As it has been indicated in table 6.9(a) above, at posttest the mean of scores of the control group was 21.87 out of 25 maximum while the mean of experimental group students was 21.73. However, no statistically significant difference was found between student posttest mean scores on the genetics test when the null hypothesis was subjected to independent samples t-test. The null hypothesis stated that there is no statistically significant difference in the posttest knowledge of genetics contents between students exposed to inquiry-based approach and those to be exposed to traditional method (TM). Independent samples t-test found the value for experimental group (M = 21.73. s.d = 1.67) and that of control group (M = 21.87, s.d = 1.93), t (261) = 0.606, p = 0.545, α = 0.05. Hence, the null hypothesis, that there is no statistically significant difference in genetics posttest scores between the control and the experimental groups was accepted at 0.05 alpha levels. Tables 5 (b) summarizes the independent samples pretest t-test of both the control and experimental groups.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Students posttest scores in Genetics	Equal variances assumed	0.136	0.713	0.606	261	0.545	0.138	0.228	-0.3	0.589
	Equal variances not assumed			-0.580	169.0	0.563	0.138	0.239	-0.3	0.610

Table 5(b): Independent samples t-test for genetics posttest scores (n= 263)
Source: Field data (2015)

As seen in table 5 (b), an analysis of independent samples t-test based on genetics posttest on experimental and control groups at alpha (α) =0.05 failed to reject the null hypothesis. This means that there were no statistically significant difference in the effectiveness of inquiry-based (IBA) approach and the conventional method (TM) in enhancing the conceptual understanding of genetics contents to students. These findings contradicts from the finding by Hadjimarcou et al. (2009) conducted a similar study to investigate the effectiveness of using an inquiry-based approach in teaching ninth-grade genetics in Cyprus. Their study involved teaching a unit of basic genetics to a control and an experimental group in the traditional teacher-centered and the inquiry approach, respectively. The results indicate that the inquiry method achieved a significantly better learning outcome compared to the traditional method. Leonard et al. (2001) found that students participating in a yearlong scientific inquiry-based Biology course posted higher gains in Biology concepts, and in the understanding of scientific processes. Furthermore, Alberts (2000) discovered that participating in scientific inquiry appears to improve retention of student learning. Leonard et al. (2001) found no differences in achievement in college chemistry between students who took an inquiry-based chemistry course in high school and those who took a traditionally taught chemistry course. The current findings do not resemble findings by Pinar &Ceren (2008) who also investigated the comparative effect of the learning cycle and expository instruction on 8th-grade students' achievement in genetics. The authors adopted the nonequivalent control group design as a type of quasi experimental design. The experimental group (n = 104) received learning cycle instruction, and the control group (n = 109) received expository instruction (conventional method). The learning cycle is an inquiry-based teaching strategy that divides the instruction into three phases: exploration, concept introduction, and concept application (Renner et al. 1988). The 2-way analysis of covariance indicated a statistically significant post-treatment difference between the experimental and control groups in favor of the experimental group after instruction.

However, as in similar studies (such as by Lewis et al. 2000 and Pinar &Ceren, 2008), students' responses in the post-test items from the experimental group in this study revealed a number of difficult learning areas that students encounter in their effort to understand genetics. They include: i) the construction and interpretation of diagrams representing Mendelian inheritance, ii) the structure, function, and correlations between DNA, genes, and chromosomes, and iii) the way meiosis, mitosis, and fertilization collectively causes the appearance of the phenomenon of inheritance. Similar results also appear in other studies (Lewis et al. 2000 and Pinar &Ceren, 2008). Watson et al. (1995) discovered that teachers used more extensive practical work in teaching science, while it had only a marginal effect on students' understanding of combustion.

4. References

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