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Comparing the effectiveness of an inquiry-based approach to that of conventional style of teaching in the development of students' science process skills

Jamal Jumanne Athuman

Department of Education, Sokoine University of Agriculture, TANZANIA

ABSTRACT

This study aimed at assessing the effectiveness of an inquiry-based approach on students' scientific process skills development 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. 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. An analysis of Biology Process Skills Test (BPST) posttest scores revealed that the experimental group students performed better in science process skills after undergoing treatments of inquiry constructivist activities as compared to their counterparts in the control group. An analysis of independent samples t-test based on type of instruction students received at (α) =0.05 produced a p of 0.047 and a t value of 0.633, hence rejecting the null hypothesis (Ho1). However repeated measures ANOVA found that regardless of the method of teaching, there were significant within-groups effects with regard to the development of science process skills.

KEYWORDS
competence based curriculum, science process skills, inquiry based approach, conventional teaching, genetics

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Introduction

Across the world, science is increasingly being viewed as a subject of life-long utility to all students, whether or not they enter science-related careers. A more science literate populace is perceived as being better equipped to contribute to the sustainable economic development and to the social welfare

CORRESPONDENCE J. J. Athuman ✉ jamal@suanet.ac.tz

(Ware, 1992). During the 1960s and 70s, science curriculum innovations and reforms were characterized by attempts to incorporate more inquiry oriented and investigative activities into science classes (Kazeni, 2005; Dillashaw and Okey, 1980). As a result, science curricula started to emphasize the acquisition of science process skills as one of the major goals of science instruction (Padilla, 1990). These reforms pushed science programs to start emphasizing the acquisition of science process skills as one of the major goals of science instruction (Padilla, 1990). The intention was to expose students to the world of science especially the world of research, laboratory experiments, and investigations so that as future scientists, they acquire scientific process skills (Padilla, 1990).

Tanzania also began a process of curriculum reform in the early 2000s, 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, student's competence in science process skills. 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 (UTR, 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).

Aim of the study

The aim of this study was to compare the effectiveness of an inquiry-based and conventional approaches to science in the development of students' science process skills

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 learners to acquire science process skills. Furthermore, the curriculum emphasized the need of Tanzania science students to learn scientific subjects such as Biology, Physics and Chemistry in the same way science is done scientists. The curriculum encourages science teachers to move from traditional methods and use participatory inquiry-based approaches as much as possible. Despite such a dramatic shift in curriculum policy, little is known about whether or not the reform efforts are truly transforming the educational experiences of students. There is no clear evidence of whether or not learners who are being taught using inquiry participatory approaches are acquiring competence in these scientific skills as prescribed in the curriculum than those who are traditionally taught. 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. 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 science process skills development of students as compared to the conventional approaches. Genetics is a focal point because the topic offers a lot of opportunities where students can practice realistic problem solving, making it suitable for inquiry-based practices.

Method

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, Cook and Campbell, 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, Manion, and Morrison, 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.

Data collection tool

The Biology process skills test (BPST) was used as a data collection instrument. The test measures five (05) individual integrated scientific skills (identifying variables, stating hypotheses, operationally defining, designing investigations and interpreting data) to advanced secondary school learners. The reliability of the instrument was established by the researcher in the year 2014 using 610 learners to be 0.80 (Cronbach's alpha). Concurrent validity of BPST was established by comparing students score in the process skills test (TIPS II) by Burns et al. (1985) and found to be 0.51. Using experts' opinion scale, the content validity of BPST was found to be 0.88. The test has reliability coefficient well above the lower limit of the acceptable range of values for reliability. It is within the range of reliability coefficients obtained from similar studies, such as those by Dillashaw and Okey (1980) who obtained a reliability of 0.89 and Burns, et al. (1985) who also obtained a reliability of 0.84. Biology process skills test (BPST) has a readability index of 72.2. This high readability value implies an easy to read text to students who English is not their first language like Tanzania students. The researcher adopted this test because it has been developed in the context of Tanzania using the Tanzania competence based curriculum.

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.

Table 1: Distribution of students by type of instruction and sex in each school

			Sex		
			Female	Male	Total
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**

Source: Research survey (2014)

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.

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.

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.

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.

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	Sex determination discussion activity

	analysis	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

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.

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, (BPST) 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. BPST was supposed to be completed within one hour (60 minutes). 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.

Data analysis plan

Both data collection tool in this particular study, the science process skills test provided quantitative data. 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 Biology process skills test (BPST) was 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.

Results

Pretest results from the science process skills test

The major aim of this quasi-experimental study was to find out whether there is a statistically significant difference in the science process skills achievement between students exposed to inquiry-based teaching (IBA) approach and those exposed to traditional method (TM). The study involved 94 (35.7%) control group students who were taught themes in genetics using the conventional method and 169(64.3%) experimental group students who were taught genetics using inquiry-based approach (IBA). An SPSS two-tailed independent samples t-test was conducted to compare pretest scores of experimental (IBA) and control (TM) classes on science process skill test (BPST) before the actual intervention. The pre-test was administered in order to determine whether the two groups were similar in terms of their level of science process skills before teaching intervention. Because the two groups were composed of advanced level students who are taking Biology and the fact that they are undergoing the same curricular materials, the study hypothesized that the two groups would not significantly differ in terms of their level of science process skills. Using independent-samples t-test and descriptive statistics this hypothesis was tested (see results table 3a and b). As it has been summarized in table 3 (a) and in the figure 1, the mean of pretest scores in BPST for the students in the control group was 15.2 out of 35 (one mark for each of the 35 items) while the mean of scores for the students in the experimental group was 15.4. The standard deviation (a spread of individual scores around their respective means) was 2.84 for the control group and 2.44 for the experimental group. This means that before genetics course intervention, the variability of the control group (2.84) was more than that of the experimental group (2.44) as shown by the coefficient of variation. This implies that the experimental group was more homogenous in terms of science process skills level than the control group before the intervention.

Table 3(a): Group statistics for BPST pretest 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	Control group	94	15.2	2.84
	Experimental group	169	15.4	2.44

Source: Field data (2015).

To verify that the two groups were matched on pretest scores on science process skills test and provide justification for interpreting gain scores for the sample, independent samples t-tests were performed comparing the inquiry and control group on pretest measures. However, no statistically significant differences in the level of science process skills were found among students of the control group and experimental group when their pretest mean scores were subjected to computer SPSS independent samples t-test. As shown in table 3 (b) below, the results of pretest scores of the IBA group (M=15.4, SD= 2.24) and that of TM classes (M=15.2, SD= 2.84); found t (261) =-1.403, p = 0.224, hence p > 0.05.The earlier hypothesis that the two groups do not significantly differ in terms of their science process skills knowledge level was accepted.

Table 3(b): Independent samples t-test for BPST pretest scores based on the type of instruction they received (n=263)

		F	Sig.	t	df	Sig. (2-t)	Mean Diff	Std. Error Diffe	95% Confidence	
									Low	Upp
Students level of process skills	Equal variances assumed	4.225	0.041	-1.403	261	0.194	0.37	-0.41	-1.04	0.21
	not assumed			-1.220	158.4	0.224	0.37	-0.41	-1.08	0.25

Source: Field data (2015).

These results from table 3 (a and b) above suggest that the knowledge levels of science process skills of students both in the control and experimental groups were comparable in terms of their level of science process skills prior to the teaching intervention. According to Reinhart & Rallis (1994) in quasi-experimental pretest-posttest studies, if groups differ at the onset of the study, any differences that occur in test scores at the conclusion will be difficult to interpret. The experimental and control groups of Morogoro Biology students, in this case, were therefore regarded suitable for comparative study.

General linear model pretest- posttest results comparison for control and experimental groups

The study was also interested in examining the within and between-group differences with respect to the development of students' science process skills over time as a result of the intervention. The best method of analyzing quasi-experimental data is to view the pretest and posttest as a repeated measures/ split-plot design or as a profile of two measurements for each subject (Green, et al. 2000). According to Field (2006), repeated measures can be used to observe both the within-person (or within-subject effects and the between-persons (or between-subjects) effects. A within-person (or within-subject) effects represent the variability of a particular value for individuals in a sample. Between-persons (or between-subjects) effects, by contrast, examine differences between individuals. According to Shuttleworth (2009) between-subjects is an experiment that has two or more groups of subjects each being tested by a different testing factor simultaneously. However, quasi-experimental data are commonly examined in repeated measures analysis. A repeated measures analysis is a measure of how much an individual in the sample tends to change (or vary) over time. In other words, it is the mean of the change for the average individual case in the sample and it is observed in one and only one treatment combination (Martin, 1996). In this study, the SPSS general linear model for repeated measures was conducted to test the effectiveness of both the conventional and inquiry methods for within- and between- groups differences in science process skills development over time. Repeated measures ANOVA for between - group differences is entitled "the effect of time on groups" and a repeated measures ANOVA for within - group differences is entitled a test of interactions effect on groups (Schindler, 2014, & Green et al. 2000).

Repeated measures analysis of variance (ANOVAs) were conducted on science process skills test (BPST) scores to compare groups' scores over the two testing occasions to test for between and within-group differences over time. The measurement of time consists of time elapsed over 08 weeks for each aspect of study with measurement at pretest (week1) and post-test (week 08). In the test of within-subjects, the within-subject factor was time with two levels (pretest in week 01 and posttest week in 08) and the dependent variables is the BPST scores at the pretest and posttest levels. On the other hand, in the test of between - groups difference, the factor was the two groups (control n= 94 and experimental group n= 169) overtime (pretest week and posttest week 8) and the dependent variable was student scores in the Biology Process skills test (BPST). The findings from SPSS general linear model for repeated measure (within and between groups) are presented in sections below.

ANOVA findings for within group (test of within - subject effects)

A within subjects ANOVA was performed on science process skills test (BPST) scores to compare groups score over the two testing occasions. As it has already been stated in section above, in the test of within-subjects, the within-subject factor was time with two levels (pretest and posttest) and the dependent variable was student scores in the BPST (pretest and posttest). The intention was to test the significance of a mean gain score of the experimental and control group in the achievement in science process skills. A Repeated measures analysis of variance is the statistical measure used to examine multiple observations of scale over time and/ or under different conditions (Schindler, 2014 & Green et al, 2000). The ANOVA tested the null hypothesis which stated that there is no statistically significant within groups (control and experimental) in the acquisition of science process skills (control and experimental) for two time periods (pretest and posttest). As it has already been stated in section above, the study involved 94 (35.7%) control group students who were taught genetics using the conventional method and 169(64.3%) experimental group students who were taught using inquiry-based approach (IBA).

Table 4 (a) summarizes the findings of SPSS general linear model with repeated measure for pretest and posttest scores within groups (experimental and control groups). SPSS computation of the general linear model with repeated measure within groups found F (1,261) = 471.081, p < 0.001, eta squared =0.643. Hence a significant main effect was noted for the time, F (1, 261) = 471, p < 0.001, which means regardless of the method of teaching there was a significant within groups effect on the development of science process skills as a result of the methods of teaching. The null hypothesis which stated that there is no statistically significant within-group effect between the control group and the experimental group over two testing occasions (pretest and posttest) with regard to students' science process skills development was rejected. Statistical significant time effects were noted at alpha =0.05 level.

Table 4(a): Repeated measures ANOVA for two time periods (the within-subjects effects for the control group n= 94 & experimental group n= 169)

Tests of Within-Subjects Effects							
Source		Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Test scores (BPST')	Sphericity Assumed	2279.03	1	2279.038	471.081	0.000	0.643

Source: Field data (2015)

According to table 6.4(a), the eta square value was acquired as 0.643. This effect size value shows that the effect magnitude is large and that almost 64.3%. This further implies that 64.3% of the change observed in the dependent variable resulted from the application of the treatments (methods of teaching). This means that both teaching methods (inquiry-based approach and conventional method) used in this study create a statistically significant difference in Morogoro Biology students' science process skills disposition scores. However, results of several studies (Rissing, et al., 2009 & Marx, et al., 2006) have shown that student' scientific process skills can be developed by using inquiry or investigative approach of teaching and learning science that gives them opportunities to practice these skills than the traditional method.

ANOVA for between - group differences (Test of between - subject effects)

The between-subjects effects determine if respondents differ on the dependent variable, depending on their group or depending on their score on a particular measure (Shuttleworth, 2009). A comparison of the groups tells about the effects of the treatments. The variability of scores within each group reflects individual differences as a result of treatment. A 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 Biology Process skills test (BPST). The results are presented in table 4 (b). According to table 6.4(b) below, the test of between - subject effects found F (1, 261) =0.471.081, p < 0.157 which means that the linear model accepted the null hypothesis. This further implies that the between- group interaction effects (method * groups* time) was not significant. Hence the null hypothesis was accepted at alpha = 0.05 level. The null hypothesis stated that "there is no statistical significant between students exposed to the inquiry-based approach (IBA) and the traditional method (TM) in their development of science process skills over time. The within-subject test indicates that the interaction of time and the group was not significant. Taking into account the findings from within-group effects, this means that there were significant gains over time and but there was no statistically significant differential improvement among groups over time. The main findings showed that both methods had an impact on the development of scientific process skills to Morogoro students.

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

Tests of within-subjects effects							
Source		Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
BPST based on Type of instruction	Sphericity Assumed	9.760	1	9.760	2.018	0.157	0.008

Source: Field data (2015).

The findings in table 4 (b) implies further that regardless of the teaching method, there was an improvement of science process skills to Morogoro Biology students both in the control and experimental groups with time. These results, however, do not support anecdotal claims that the inquiry-based method of teaching is more effective than the traditional lecture method of teaching in science process skills development. These findings led the researcher to conclude that there is no a single best or effective method of teaching in each context. Effective teaching method according to Seldin (1999) is any approach which produces beneficial and purposeful student learning through the use of appropriate procedures. For example, in this case, the study indicated interaction effect between time and treatment groups meaning that the experimental and control groups but had no significant differential improvements over time.

Comparing the general performance of control and experimental group in BPST

To determine statistically if there were a significant difference in students' science process skills achievement between those exposed to the inquiry-based teaching of genetics and those exposed to the traditional method, an analysis of BPST posttest mean scores was carried out. Two independent samples t-test was conducted to follow up the significant interaction and assess differences among teaching method groups at the end of intervention period. The two groups (control and experimental) were firstly given the pre-test and then and intervention of 08 weeks before completing the same post-tests. The testing effects and influence of teacher variables across all the groups were nullified so that the post-tests of each of the experimental groups could be compared with that of the control group to detect the effects of treatment/ intervention.

The mean scores and standard deviations of two groups are shown in table 5 (a). The results of mean scores between the control and experimental groups on BPST have been represented also in a bar graph in Figure 2. The mean of students score in the experimental group was 19.7 out of 35, while the mean of the control group 19.1 out of 35 items. The spread (standard deviation) of individual scores around their respective means changed from 2.84 to 1.82 for the control group and from 2.44 to 1.97 for the experimental group. Contrary to pretest results, the variability the experimental group (1.97) was more than that of the control group (1.82) as shown by the coefficient of variation in the table (5 a) below. Hence the experimental group, in this case, was found to be a bit more variable than the control group implying that the control group was more homogenous than the experimental group after intervention (posttest).

Table. 5(a): Group statistics for BPST 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	19.7	1.822
	Conventional method	94	19.1	1.973

Source: Field data (2015).

To establish whether the difference in mean scores between the control group and experimental group were statistically significantly or not, an SPSS independent samples t-test analysis was carried out. The results from independent samples t-test of mean scores are shown in table 6.5 (b). According to the table (5 b), a statistical significant difference was found on students' posttest scores based on the type of instruction they received when the null hypothesis (Ho1) was subjected to computer SPSS independent samples t-test. An analysis of independent samples t-test based on the type of instruction students received at (α) =0.05 produced a ρ of 0.027 and a t-value of 0.633, hence rejecting the null hypothesis (Ho1). The null hypothesis stated that "there is no statistically significant difference in students' science process skills achievement between those exposed to inquiry-based teaching (IBA) and those exposed to traditional method (TM)". It means that there was statistically significant difference in students' science process skills achievement between those exposed to inquiry-based (IBA) and those exposed to traditional method (TM) in favor of the experimental group. The null hypothesis was rejected at 0.05 alpha levels.

Tables 5 (b) below summarize the independent samples t-test of scores based on students grade level.

Table 5(b): Independent samples t-test for BPST posttest scores based on type of instruction they received

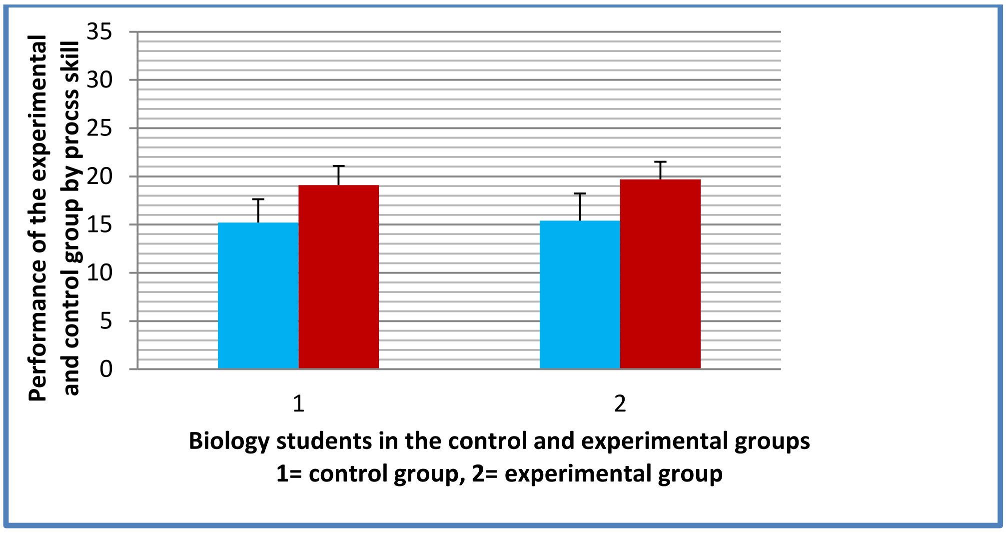
		F	Sig.	t	df	Sig. (2-t)	Mean Diff	Std. Error Diffe	95% Confidence	
									Low	Upp
Students level of process skills	Equal variances assumed	1.62	0.204	0.633	261	0.027	0.153	0.241	-0.322	0.62
	not assumed			0.619	179.7	0.037	0.153	0.247	-0.334	0.64

Source: Field data (2015).

As indicated in tables 5 (b), a t-test revealed a statistically significant difference between the mean score of control group students who were taught traditionally (M = 19.7, s.d = 1.822) and that of the experimental group(M = 19.5, s.d = 1.973), found a t (261) = 0.633, $\rho = 0.027$, $\alpha = 0.05$ ($p<0.05$). It may be argued that students exposed to the inquiry based approach (the experimental group) had the opportunity to observe, discuss, interact and interpret data as they were. Hence it can be suggested that emphasis on students' participation in inquiry based lessons might have assisted the experimental groups to perform better in science process skills than the control groups students. It is in the view of this study that the teacher-centered mode of teaching science in the sampled schools, which did not allow the Biology students to practice and internalize the skills over a fairly long period. This might be one of the main reasons for the even experimental group students' poor performance on the many science process skills investigated.

Graph 1 below shows how the control and experimental group students performed science process skills test at pretest and at posttest occasions.

Graph 1: Performance of control group vs experimental group in the pretest and posttest



These results, however, support claims put forward by the Tanzania competence based syllabus (URT, 2005) that the inquiry-based method of teaching is more effective than the traditional method of teaching in science process skills development and hence should be adopted by science teachers. On the other hand the findings from this study that experimental group students who were taught genetics using inquiry-based approach (IBA) outperformed control group students in science process skills resembles findings from many previous studies. For example, Lee and Butler (2003) examined the effect of designing and using inquiry tasks in increasing scientific knowledge and problem-solving skills. A sample of the study consisted of 59 male and female students who performed a set of real inquiry tasks (prediction, measurement, decision making). Results of the study indicated that the used teaching method was effective in promoting students' scientific understanding, enriching their knowledge base and their problem-solving ability which in turn contributes in preparing students to be active participants in the community.

The findings from the current study also resemble the findings put forward by Ghabayen (1982) who conducted a study to identify the effect on inquiry teaching method on preparatory school students' acquisition of physics concepts and scientific methods. A sample of the study consisted of (16) seventh-grade sections containing (228) male students and (340) female students assigned randomly into two groups: the first group was the experimental study group taught using the inquiry teaching method and the second group was the control and was taught using the traditional teaching method. The researcher used an achievement test and scientific methods test. Results of the study indicated that students in the experimental group students outperformed control group students in the physics concepts achievement test and in the acquisition of scientific methods.

Brian at al. (1994) conducted a study on a group of basic stage student teachers. A sample of the study was divided into (4) groups taught using (4) different teaching methods to identify the effect of each of these teaching strategies on students teachers acquisition for integrated science processes. Results of the study indicated that the cooperative learning group and lab activities based teaching method significantly outperformed students taught using the traditional teaching methods in acquiring scientific inquiry processes. However, this is not always the case that students exposed to inquiry-based teaching will always have good achievement in science process skills. Sometimes the acquisition of process skills is quite negative with an inquiry-based approach. For example, a study by German et al. (1996) examined and evaluated 7th-grade students' perceptions towards scientific inquiry processes skills. The study focused mainly on data recording, data analysis, data representation, findings representation and providing scientific evidence skills. A sample of the study consisted of (364) 7th-grade students and the Alternative Assessment of Science Process Skills (AASPS) to identify students' acquisition of scientific inquiry processes. Results of the study indicated that only (61%) of students were successfully able to perform the data recording related activities and that (69%) of students have not reached the required level in findings data representation skills in the designated activities. About 81% of students were not able to provide supportive scientific evidence to support the findings obtained in certain activities. However an exploration of the effect of directed inquiry approach integrated several learning strategies such as advance organizers, the learning cycle, concept maps, etc., on learning of science process skills by Germann (1996) reported that the directed inquiry approach to learning had no significant effect on the learning of science process skills or on cognitive development.

Conclusions

In this study, students who were taught genetics through the inquiry-based teaching approach attained higher scores in the BPST than those taught through the conventional lecture method. The results revealed that using hands-on learning activities had a positive effect on students' development of science process skills. Based on these findings, this study proposes the following recommendations:

i. Education authorities in Tanzania should encourage science teachers to use this approach and teacher training institutions to make it part of their teacher training curriculum content. Teacher training colleges and universities offering Education courses should be designed to produce teachers capable of planning, designing and implementing inquiry-based teaching modules, lessons, and approach.

ii. Teachers in schools should be given training in planning and implementing inquiry-based teaching approach through in-service courses and orientations. This may be an effective teaching approach in providing suitable learning conditions for students of diverse learning styles and academic abilities that is common in most classroom settings. Students learn science best when the teaching methodology enables them to get involved actively in class activities. They should participate actively in doing experiments, carrying out demonstrations, class discussion and other relevant learning experience.

iii. The study found a statistically significant difference in performance of science process skills between the experimental group and the control group which was taught using the conventional method. The experimental group had better mean score than the control group taught using the conventional method.

This result may be investigated for further confirmation. A blend of models may be used because there is no single model that is exclusively best for teaching all the topics at all levels to all students, considering individual differences among students.

iv. The study was carried out in relatively crowded classrooms. The average population of the students per classroom was about 40 science learners. The lessons were given as based on hands-on activities under those conditions and the results achieved are particularly significant in that respect.

Disclosure statement

No potential conflict of interest was reported by the authors.

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