FOSTERING HIGH, MEDIUM AND LOW ABILITY SENIOR SECONDARY SCHOOL STUDENTS' GENETIC ACHIEVEMENT UTILIZING INTEGRATED STEM APPROACH IN MINNA, NIGER STATE

BY
Yaki, Akawo Angwal: School of Science and Technology Education
Federal University of Technology, Minna, Niger State

Bawa, Saratu: School of Science and Technology Education
Federal University of Technology, Minna, Niger State
&
Nmadu, K. Rachel: School of Science and Technology Education
Federal University of Technology, Minna, Niger State

Abstract
Promoting equity among learners with different abilities is an important goal of science education. Lack of equity could be detrimental to medium and low ability students' interest, and achievement in science. Consequently, this could negatively impact national development. Thus, this study enhancing high, medium and low ability senior secondary school students' genetic achievement employing integrated STEM approach was examined. Quasi-experimental pretest, post-test control group design. The sample size consisted of 100 senior secondary school students. Using simple random sampling, fifty-one students with different academic abilities (low, medium and high) were assigned to the experimental group. While 49 low, medium and high ability students to the control group. The experimental group was instructed on the topic of genetics with Integrated STEM Approach (ISTEMA) which is a five-phased iterative cycle. The control group learned with traditional teaching method. Pre-test and post-test data were collected using 40 choice questions adopted from the West African Senior Secondary Certificate Examination (WASSCE). Analysis of Covariance (ANCOVA) and dependent t-test was used for data analysis. The findings showed there was a significant main effect between high, medium and low ability students that learn using ISTEMA and those taught using traditional method. There was also no significant interaction effect between the instructional approach and students' academic ability, which meant that students' ability and instructional approach did not interact to enhance students' achievement. The overall findings indicated that high, medium and low academic ability students benefitted, but with the low ability students having the highest mean gain. It was recommended among others that teachers should be encouraged to employ instructional approaches characterise by defining problem, generation of ideas, designing solution.
Keywords: STEM education, ISTEMA, Genetic achievement, and Students' ability

Introduction
Promoting meaningful learning of science education has been a vital objective of science teaching and learning globally. This can be seen in the continuous search for innovative instructional, and assessment strategies to enhance meaningful learning. One critical aspect of instruction is to involve and assist both high, medium and low ability students in the instructional process towards achieving desired instructional objectives. Nevertheless, achieving equity among low, medium and high ability students is a persistent and enduring challenge. Therefore, instructional equity for high, medium and low ability should be of paramount concern for educators during the instructional process. Shahali, Halim, Rasul, Osman, and Zulkifeli (2017) suggested that raising students' achievement for all students in science, and related subjects is an absolute necessity if they are to compete and remain competitive in the global market. Hence, the current science instruction will be a challenging task for educators if they lack the knowledge and understanding of the critical issues to consider. One of such issues is student's ability because it is a factor that makes or mars students' achievement in science (Gambari, James, & Olumorin, 2013).

Meaningful and efficient learning that culminate in improve performance does not depend on the teacher capabilities alone. But on the instructional approach and environment that will provide quality learning experiences for different types of learners (Karpudewan & Chong, 2017). Students respond differently to different instructional approaches based on their academic abilities. Therefore, there is the need to critically consider the instructional strategy that will address students' learning differences. Thalib, Corebima, and Ghofur (2017) accentuate that educators should employ students centred instructional approaches that will enhance mastery of the learning content and cater for individual learning differences.
Ability group are the groupings of students based on their Intelligent Quotient (IQ) or academic achievement. Previous literature has reported achievement gap between high, medium and low ability students at national and international levels especially in teacher-centred classroom environment (Gambari et al., 2013; Han , Capraro, & Capraro, 2015; Yaki, Saat, Sathasivam, & Zulnaidi, 2019; Yu, She, & Lee, 2010). Teachers believe that it is not appropriate to teach students with low abilities complex and abstract learning content because they may not cope with a complex task (Yu et al., 2010). It is reported that there is significant difference between high ability, medium and low ability in favour of high ability students in science (Gambari et al., 2013; Raes, Schellens, & De Wever, 2013). In contrast, low ability students perform better than high ability students in a non-traditional approach; approaches that engage higher mental abilities (Han et al., 2015; Thalib et al., 2017).

Although, some of these researchers have researched factors responsible for the achievement gap between students with different abilities with a view to reducing the achievement gap, yet the gap has persisted. Therefore, reducing this gap could require the adaptation and implementation of an instructional approach that will address students' individual learning needs. Consequently, an important way to help all students learn effectively is by employing innovative and active instructional approach that enhances students' active exploration leading to quality learning (Sailin & Mahmor, 2018). One such strategy is the integrated STEM approach which is characterized by minds-on and hands-on activities, among others which enhance students' active engagement in the learning process (Arıkan, 2018; Shahali et al., 2017).
Teaching and learning become integrated when instructional contents of two or more subjects' areas are presented to learners such that transfer of knowledge is facilitated (Laboy-Rush, 2011). Integrated STEM-based approach could improve students' performance because it is a non-traditional instructional strategy that is characterised by learners' exploration through active engagement. Krajcik (2015) highlights that STEM education engages and enhances the learners' classroom positive experiences.

However, there are mixed findings from the literature on the effects of STEM education instruction on student's achievement (Berland, Steingut, & Ko, 2014; Guzey, Harwell, Moreno, Peralta, & Moore, 2017; Wendell & Rogers, 2013). Guzey et al. (2017) in their study on the effects of design-based STEM instruction on students' achievement in middle school, the findings show significant learning gains in physical science content but no significant learning gains in life science and mathematics. Han, Rosli, Capraro, and Capraro (2016) discovered that STEM-based learning improved students achievement in mathematics but did not improve science achievement. Acara, Tertemizb, and Taşdemirc (2018) reported the effect of STEM-based instruction on mathematics and science achievement, the findings indicated that students improved in their science and mathematics scores. They recommended further research in this area will add to existing literature by considering students' academic abilities (high, medium and low). Nevertheless, there are limited studies on the effects of STEM approaches on the achievement of students in science based on high, medium and low ability student. Probably, because STEM based approaches are relatively new (Wang, Moore, Roehrig, & Park, 2011).

Statement of the Problem

Development in the field of genetics such as a genetically modified organism, cloning, and genetic disorders raises fundamental educational, ethical and economic questions. That could contend that the present generation needs a better understanding of genetics. Nevertheless, a glean at the literature shows that both teachers and students experience difficulties to teach and learn genetics respectively

(Agboghoroma & Oyovwi, 2015; Atilla, 2012). Factors responsible for these learning difficulties include the abstract nature of genetics because its processes are cellular (Agboghoroma & Oyovwi, 2015). Genetics is multidisciplinary involving probability in mathematics and its application in bioengineering (Chu & Reid, 2012). Therefore, approaching the learning of genetics from a traditional approach as observed in the present classroom could have contributed to the learning difficulties. Thus, students' genetic achievement continues to be unacceptable (Danmole & Lameed, 2014). Consequently, an integrated STEM approach that is interdisciplinary could provide an efficient way to learn genetic. Because hands-on and minds-on activities characterise integrated STEM approach. Engaging students in hands-on activities could help to make the abstract nature of genetics concrete for meaningful learning to take place. One of the fundamental ways to promote learning for all students is by engaging them actively in the learning process and that can be achieved through hands-on and minds-on activities (Thalib et al., 2017). Several literature that reported that team project and learner centred activities make abstract genetic processes concrete, thereby improving students' academic performance in genetics (Mandusic & Blaskovic, 2015; Monvises, Ruenwongsa, Panijpan, & Sriwattanarothai, 2011). This implies that teachers must create learning environment that will cater for low, medium and high ability students. The lack of equity or the presence of achievement gap between high, medium, and low ability students especially in traditional classroom environment could impact negatively on the interest and achievement of low and medium ability in science and subsequently their choice in STEM careers. Hence, the motivation for this study.

Research Questions

These research questions were stated to guide the study;

1. Are there any significant differences between high, medium and low ability students that learn integrated STEM approach and traditional method on senior secondary school students' genetic achievement?
2. Are there significant differences in genetic achievement among high, medium and low ability students of the integrated STEM approach group?

Research Hypotheses

The following research hypotheses were formulated and tested at 0.05 significant level;

Ho$_1$: There are no significant differences in the main and interaction effects between students that learn integrated STEM approach and traditional method on senior secondary school students' genetic achievement?

Ho$_{2:}$ Are there significant differences in genetic achievement among high, medium and low ability students of the integrated STEM approach group?

Methodology

Quantitative design was adopted. Specifically, Quasi-experimental pretest, post-test control group design was adopted for this research. The population of this study was 5,044 senior secondary school biology students from five Federal Unity Schools in Niger State, Nigeria. The target population of this study was 539 senior secondary school biology students in five Federal Unity Schools. Two schools were purposefully chosen and were randomly assigned to the experimental and control group. The sample size was one hundred (100) students. The experimental group was made up of fifty-one (51) randomly selected. The students in the experimental group consist of high medium and low ability which were 15, 20 and 16 respectively. On the other hand, the control group were 49 students: high (15), medium (19), and low ability (15). In this study, the researcher used the average prior science performance in the previous year, to classify students' different ability; $\geq$ 70% as high, $\geq$ 50 - 69%, medium and $\leq$ 49 as low ability (Zady, Portes, & Ochs, 2003).

A genetics (genetic laws, terminology and probability) achievement test made up of forty (40) multiple choice questions adapted from National Examination Council (NECO) and West African Examination

Council (WAEC) was used as the instrument for data collection. The test was pilot tested to determine its reliability, the test was administered once and using the split-half method the data collected was analysed and the reliability coefficient was 0.84 which was considered suitable for this study.

Intervention

The intervention lasted for eight weeks. In the first week the pre-test was administered, and students assigned to a group of five students each. The groups are heterogeneous in ability and mixed in gender. Teachers were trained to implement the intervention and the intervention started at the same time for all the groups. The experimental group was instructed using a five-phased ISTEMA iterative process called ISTEMA instructional material. The five-phased iterative process (Understand problem, Generate ideas, Design solution, Evaluate solution and Communicate ideas) was adopted from engineering design process from literature Improve (English, 2016; Shahali et al., 2017). The approach could provide learners with exciting learning experiences that are less disjointed and more relevant to problem-solving in real life (Moore et al., 2014). The approach is learner-centred and provides the students with the opportunity for active engagement which could enhance meaningful learning.

The ISTEMA instructional material is a written guide or material on genetics as a unit of instruction. It was prepared to enhance students' achievement in genetics and critical thinking skills, but for this research paper, we shall be dealing only with students' achievement based on their academic ability. The objectives of the lesson were drawn from genetics terminology, laws and probability which was studied using the ISTEMA iterative process. Students explore instructional materials individually and then meet in a group to brainstorm their ideas. The teacher drives the entire process through facilitation by providing clues and question prompts to facilitate the learning process. The students are presented with an engineering design-based, open-ended and real-world problem which served as a context to learn the science content (Genetics). The problem is; the savannah Hare is a wild rabbit has an estimated length between 41 – 58 cm. This animal is threatened by eradication, and your group is contacted by a zoologist to engineer a unique Hare that will benefit the society.

The application of this material on the topic of genetics is as presented in Table 1.
Introduction: Given the problem presented above students are expected to activate their prior knowledge using KWLH sheet; what do you know about the problem and what do you need to know and how do we proceed?

Table 1: ISTEMA Iterative Process

Phases	Description	STEM Disciplines
Engaging problem	Highlighting the components of the problem and stating the requirement of the problem and constraint Highlight the goal of the problem Group collaboration on the problem	Science and engineering
Generation of Ideas	Generate ideas about genetic laws (Mendel's first and second law)	Science (genetics)
	Principles of combination dominant and recessive characters among others	Algebraic thinking and probability (Mathematics)
	Principles of Expression (genotypes and phenotypes)	
	Information on genetic engineering procedures; extraction, isolation and insertion Brainstorming on the best idea	Engineering and Technology
Design and Construction of	Sketching their ideas	Engineering and Mathematics

the solution		
	Translating their ideas into a 2or 3D Measuring of materials and sticking Group project	Mathematics and Technology
Evaluation	Evaluating the solution; such as, are the requirement met? Why or why not?	
Communication of Findings	Students reflect on the entire process and present their findings	

Students worked individually within specified time in each phase and met at the end of each phase to share their ideas. Each student has an ISTEMA worksheet to record his/her ideas before meeting in their individual groups to share and defend their ideas. Group members probe each other's for justification before reaching a consensus on the best idea. The control group was instructed with the traditional teaching method which is based on teachers' explanation from the textbooks.
Data collected from pre and post-test were analysed based on the stated research questions. Mean, Standard Deviation and Analysis of Co-variance (ANCOVA) was used to analyse the data.

Results
Firstly, Pre-test of the genetic achievement test was administered to both experimental and control group high, medium and low ability students before the intervention began. Data from pre-test was used to determine the similarity of the groups before the intervention as presented in Table 2

Table 2: Pre-test Result of Experimental and Control groups High, Medium and Low abilities

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	558.669	5	111.734	2.715	.025
Within Groups	3868.321	94	41.152		
Total	4426.990	99			

* Significant at $p<.05$

Table 2 shows the pre-test result of the experimental and control groups high, medium and low achievers. The results show a significantly different $F(5, 94) = 2.715$, p (.02) <.05. This suggests that the two groups were not similar with regards to their science achievement before the intervention. Therefore, the pre-test score of science achievement was used as co-variates to mediate the initial differences between the two groups.

Post-test Result
This section determines the effect of intervention by comparing the post-test data of students instructed with integrated ISTEMA approach and traditional teaching method. The analysis was presented based on the stated hypotheses.

Ho_1. There are no significant differences in the main and interaction effects between students that learn integrated STEM approach and traditional method on senior secondary school students' genetic achievement? To test this formulated hypothesis, Analysis of Co-Variance (ANCOVA) was carried out to determine the main effects and interaction effects between the independent variables (instructional approach and students' ability). The pre-test was used as the covariates. The result is as presented in Table 3;

Table 3: ANCOVA Results High Medium and Low Ability Group of Experimental and Control Group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	838.019[a]	6	139.670	3.797	.002	.197
Intercept	4823.186	1	4823.186	131.133	.000	.585
Pre-test	33.456	1	33.456	.910	.343	.010
Ability	838.006	5	167.601	4.557	.001	.197
Error	3420.621	93	36.781			
Total	160758.000	100				
Corrected Total	4258.640	99				

Table 3 shows ANCOVA analysis of high, medium and low ability students of the experimental and traditional group. The result shows F (5,93) =4.55, p (.01) < 0.05. Indicating that, there is significant difference among the high, medium and low achievers of the experimental and traditional group. Therefore, the hypothesis which states that there is no significant difference in genetic achievement among high, medium and low academic achievers between selected senior secondary school students that learn with iSTEMa and those who learn using the traditional method is hereby rejected. The partial η^2 = 0.197 indicates that the treatment accounted for 20% of the total variance in students' achievement in genetics. The significant difference is in favour of the high medium and low ability students of the experimental group which has the means of 40.47, 40.35 and 44.50 respectively. While the means of high, medium and low achievers of the traditional group are 38.93, 38.22, and 34.87 respectively. The mean indicates that the control group high ability students perform better than the medium and low ability students. Thus, showing an achievement gap between high, medium and low ability students in traditional instructional classroom The post-hoc multiple comparison was conducted to detect the direction of the significant difference and the results is presented in Table4.

Table4: Post-hoc Multiple Comparison

(I) Ability	(J) Ability	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
ExpLow	ExpHigh	4.481	2.230	.517	-2.219	11.181
	ExpMedium	4.114	2.035	.507	-2.000	10.228
	ConHigh	6.101	2.251	.113	-.662	12.864
	ConMedium	6.663*	2.123	.034	.285	13.042
	ConLow	9.945*	2.170	.000	3.423	16.466

ExpHigh (experimental high ability); ExpMedium (experimental medium ability); ExpLow (experimental low ability); ConHigh (control high ability); ConMedium (control medium ability) and ConLow (control low ability). Table 4 shows sidak post-hoc multiple comparison. The significant difference was found between the low ability of the experimental group and medium ability of the control group with the mean difference of 6.66 and p(.03). Similarly, there is a significant difference between the experimental low ability and the control low ability with the mean difference of 9.95, p(.01). This implies that the low achievers of the experimental group benefited more.

$H0_{2:}$ Are there significant differences in genetic achievement among high, medium and low ability students of the integrated STEM approach (experimental) group? To determine whether the mean difference between high, medium and low Abilities was significant ANCOVA was used while the covariate is the pre-test and the result is as presented in Table 6

Table 6: ANOVA Result of High, Medium and Low Ability Students of the Experimental Group

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	184.697	2	92.349	2.109	.133
Within Groups	2102.283	48	43.798		
Total	2286.980	50			

Table 6 shows ANOVA result of high, medium and low ability students, the data yielded an $F(2, 48) = 2.11$, P (0.133) > .05, hence, there is no significant difference between high, medium and low ability students instructed with integrated STEM approach. The n^2 (0.03) indicates that only 3.0% of the total variance was attributed to the effect of ISTEMA. The estimated means were 40.46, 40.35 and 44.50 for high medium and low ability students respectively. Indicating that, even though there was no significant difference between the three groups the lower ability means (44.50) is higher than medium (40.35) and high ability (40.46). Indicating that integrated STEM approach could have provided conducive learning environment for students with different abilities

Discussion

The study determined the effects of integrated STEM approach on high, medium and low ability secondary school students' achievement in science. High, medium and low ability students exhibited different achievement rates which suggest that instructional environment influence learners' academic achievement differently based on their academic ability. There was a significant difference among high, medium and low ability students of the experimental and control group. This finding concurs with Acara et al. (2018) reported the effect of STEM-based instruction on mathematics and science achievement, the findings indicated that students improved in their science and mathematics scores. The result is contrary to the findings of Han et al. (2015) who reported that there was no significant difference between the achievement of students taught sience with STEM-based approach and non STEM-based approach. The findings of this study seem to indicate that the integrated STEM approach offers a promising instructional environment that supports, motivates and engages the learners in collaborative and active learning.

The result indicated that high, medium and low ability all benefited. There were no significant difference between high, medium and low ability students taught with integrated STEM approach. However, the low achieving student had the highest mean gain compared to the high and medium ability. This finding agrees with Yu et al. (2010) and Han et al. (2015) who reported that low ability perform better than high ability students using non-traditional approaches. This may be attributed to the low ability students learning in a social context through cooperation and collaboration. In line with Gambari et al. (2013) who established that low ability performed at the same level with high ability students if not better in cooperative learning setting. It also concurs with Taber (2010) who highlighted that social constructivist theory suits classroom instruction of students with different abilities. Low ability students benefited more than high and medium ability students, suggesting that ISTEMA is appropriate for students with different learning abilities.

This suggested that the approach provided the student the opportunity to explore genetics and integrate knowledge from other STEM discipline to solve open ended problem that was real-world as a team. This agrees with several literature that reported that team project and learner centred activities make abstract genetic processes concrete, thereby improving students' academic performance in genetics (Mandusic & Blaskovic, 2015; Monvises et al., 2011). Given the proceeding, it may be reasonable to assume that low achieving students who encounter learning difficulties in the traditional classroom because of its teacher centred and passive nature benefitted more by engaging actively and through support from their peers, and the teacher

Conclusion

Equity and access to all students irrespective of their abilities in science instruction are of paramount important. Thus, ISTEMA has demonstrated improvement in the achievement high, medium and low ability students. Hence, reducing the achievement gap between high, medium and low ability students. In view of the findings, a logical conclusion will be that instructional approaches characterise by defining problem, generation of ideas, designing solution and evaluation in collaborative environment will enhance students' achievement in science irrespective of their ability. Generally, this research work provided an understanding of classroom practices, especially during the implementation of the integrated STEM-based approach to instruction that all students can learn if the correct approach is used. It clearly indicates that students' achievement will be enhanced through the instructional environment that is student-centred and characterized by STEM elements. To consolidate on these findings, a similar study can be carried out on students in different classes and settings. The integrated STEM approach and instructional material can also be applied to other moderating variables such as gender, socio-economic status, and school location.

Recommendations

Given the findings of the study, the following recommendations are relevant:

1. Teachers should be encouraged to employ instructional approaches characterise by defining problem, generation of ideas, and designing solution among others
2. Teachers training institution should include integrated STEM approach into their curriculum to prepare pre-service teachers to implement it in the classroom
3. Policymakers and curriculum developers should design policies that will supports integrate approaches that are characterized by real-world context into the curriculum

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