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Effects of the Mercedes Model with Embedded Assessment Strategy, Subject Specialisation and Gender on Students' Knowledge of Selected Biology Contents

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Abstract

This study investigated the effects of the Mercedes Model with Embedded Assessment Strategy, subject specialisation and gender on students' knowledge of selected biology concepts. A pre-test post-test control group quasi-experimental research design was adopted for the study. The sample consisted of 666 Senior Secondary Class II biology students from six senior secondary schools randomly selected from two purposively selected Education Districts (EDs) in Lagos State. The two EDs were randomly assigned to treatment such that one was the experimental group and the other the control group. Seven null hypotheses were formulated to guide the study. Also, five instruments were used to generate data for the study, namely, the Mercedes Model with Embedded Assessment Strategy in Diffusion (MEASID), Mercedes Model with Embedded Assessment Strategy in Osmosis (MEASIO). Conventional Lesson Plan on Diffusion (COLPOD), Conventional Lesson Plan on Osmosis (COLPO) and Test on Students' Learning Outcomes in Osmosis and Diffusion (TESLOOD). Data collected were analysed using mean, standard deviation, analysis of covariance (ANCOVA) and multiple classification analysis. The study has shown that the use of the Mercedes Model with Embedded Assessment Strategy has positively improved students' knowledge of selected biology concepts. Further, the biology students in the science class were better than the non-science group at imbibing the knowledge of biology concepts. In the same vein, the males performed better than their female counterparts in knowledge. It was recommended, among other things, that teachers of biology adopt the Mercedes Model with Embedded Assessment Strategy in the teaching of students in secondary school.

Keywords: Mercedes Model, Subject Specialisation, Gender, Knowledge, Selected Biology Concepts

Introduction

Biology is conceptual in nature; this on its own constitutes difficulty for the students. Added to this is the fact that in most schools, the subject is still offered to all students from the different specialisations, thus making the number of students a Biology teacher would have to attend to always large. The two reasons emphasised above contributes to the difficulty students encounter in the Biology class and this consequently affects students' performance in the subject. According to Ali (1984); Okeke (1986); Olanrewaju (1986); Okebukola (1997); Baron (2000); and Nwagbo (2001), the most common factor responsible for poor performance is the inappropriate and uninspiring teaching strategies adopted by science teachers.

Experience has shown that most strategies that failed to produce the expected result of enhanced student performance had always expected the students to regurgitate the right answer (whether or not they understood) or focused on the product rather than the process of arriving at the answer. Taking the above into consideration, there is a need for a teaching strategy that emphasizes the process of arriving at an answer rather than simply requiring students to regurgitate the "right" answer – whether or not they understand either the answer or its justification. Also, there is a need for a strategy that focuses on process, not product, and provides content for the information that students acquire and is effective and flexible. This strategy is in conformity with the 21st century reforms in science education.

The 21st century reforms in science education have the following characteristics:

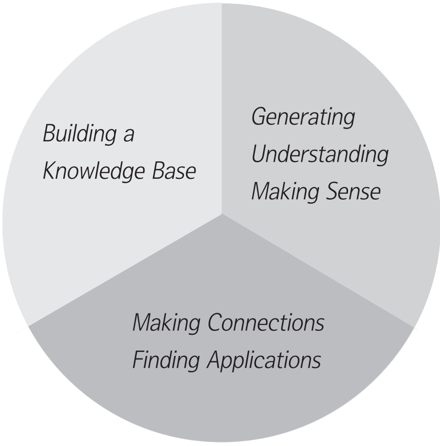
Knowledge is not a commodity that can be transmitted but the result of individual, personal transformation of factual elements and relationships into a coherent form by the learner. In concise terms, this vision holds that knowledge must be constructed by individual learners.

Teaching is viewed as guiding the students toward a valid construction of knowledge, recognizing that an unguided construction of knowledge frequently does not conform to the scientific canon. Learning is the process of making sense of new information and reconciling new and prior knowledge to create a new level of understanding and application. According to Gallagher (2000), if teachers are to participate in the contemporary reform in science teaching, it is essential that they adopt this new vision about teaching and learning and abandon the former one. This is the foundation of Gallagher's Embedded Assessment Strategies and his Mercedes Model for teaching and learning science for understanding and application.

Gallagher (2000), after exploring different conceptual models of teaching and learning formulated a model that has been useful in helping teachers see their role in teaching for the understanding and application of science knowledge more vividly. The model is called the Mercedes Model for obvious reasons as it points to three aspects of teaching for the understanding and application of knowledge – (i) building a knowledge base (acquisition of factual information),

(ii) generating understanding (in the straight forward terms of making sense of information and making connections between new information and students' existing ideas), and (iii) finding applications (making connection between concepts and the real world" experience) (Fig. 1.1). One feature of this model is that it helps teachers to comprehend that each of these three components of learning for understanding and application requires different teaching strategies.

Figure 1. Mercedes Model



In all, Gallagher identified 13 teaching/assessment strategies for the Mercedes Model which are:

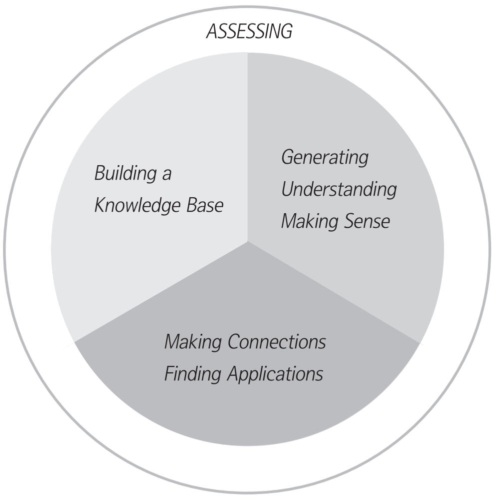
Table 1. 13 Teaching/Assessment Strategies for Mercedes Model

S/N	Strategy	Description
1	Journal Writing	Any of the strategies described below can be the basis for an entry in students' journals. Journal writing is an effective way of hearing what students are thinking and understanding.
2	Mind Stretcher	A question or a set of questions posed by the teacher that students answer individually, with a relatively brief written response.
3	Student Generated Questions	Students formulate questions that they wish to have answered or are puzzled by. Students can direct the questions towards themselves, peer, teacher, or other predetermined audiences.
4	Peer Analysis	Students analyse, expand on, and/or modify (anonymous) examples of classmates' work. This can be used in conjunction with any of the other strategies.
5	Models, Pictures and Diagrams	Students explain general concepts or specific phenomena using a model, picture, or diagram, as an alternative way of thinking about something. Students can create these themselves or use one suggested by the teacher. Students can work from an alternative representation to the idea or vice versa. (A verbal or written explanation included for the interpretation of the picture, diagram, or model is an important part of this strategy.

S/N	Strategy	Description
6	Concept Mapping	Students generate pictorial representation of the connection between ideas.
7	Preposition Generation	Students write one or two sentences explaining the connection between two concepts.
8	You Become The Teacher	Students are assigned the task of preparing and teaching a lesson on a particular topic or idea to a specific group. Students can work individually or in small groups to prepare a written plan for how to teach the topic. If possible, students should actually teach the lesson to a real student body or audience.
9	Making and Interpreting Graphs	Students make graphs based on their own or other data and then use the graph to answer questions or explain their experiment.
10	Laboratory Demonstration	Students or teacher use equipment or materials in order to experience a phenomenon, become familiar with equipment or develop measuring skills. They then try to explain the phenomenon or write about how they would use the skills or equipment.
11	Laboratory Experiments/ Record Observations	Students design, perform, and/or analyze controlled experiments. Students can do any part or parts of this process.
12	Inquiry Projects	Students explore an object or a phenomenon with the intent of understanding it. The project can take many forms. Students can chose a topic or choose the means to a given end. Throughout the process the students have opportunities to direct the inquiry within certain limits.

For the Mercedes Model to be an effective model of instruction, Gallagher (2000) asserted that it is essential that an overlay of continuous formative, embedded assessment be added (see Fig. 2). This is in line with the framework of constructivist teaching (Brooks and Brooks, 1998).

Figure 2. Mercedes Model and Embedded Assessment



Also, researches have shown inconsistent findings on gender differences and academic achievement (Gimba, 2006; Nsofor, 2006; Yaki, 2006 and Olowe, 2010). There is therefore the need to find out if gender has effect on students' knowledge in Biology. Given that Biology is still made compulsory for both science and non-science students in some schools this study would also compare the performance of the two groups in order to determine if subject specialisation has an effect on students' knowledge of Biology.

Statement of the Problem

Research has shown that students perform poorly in Biology and the large classes have been difficult for teachers to manage (Ajewole, 1984, Illoputaife, 2000, Akinolu, 2006, Abimbola 2013). The ineffectiveness of the strategies traditionally employed by science teachers has been attested by several researchers (Okebukola et. al. 1990, Baron, 2000, Ndioho, 2007, Hassan and Ogunyemi 2008). A number of teaching strategies have been employed in teaching biology over the two decades yet the performance of biology students in the Senior School Certificate Examination (SSCE) still remains poor. Biology students have often failed to develop competencies and skills to a passable level as adjudged by the West African Examination Council (WAEC). The observation is deduced from the poor performance of students in Senior Secondary School Certificate Examination (SSCE) reported by the West African Examination Council as presented in Table 2.

Table 2. Percentage Distribution of Students' Performance in May/June Senior Secondary Certificate (SSCE) in Biology in Nigeria: 2002 - 2012

Year	Total Entry	Total Sat	Credit Passes 1-6	Percentage Passes
	No. of Candidates	No. of Candidates	No. of Candidates	% of Candidates
2002	1,240,163	882,119	278,112	31.52
2003	1,006,831	909,101	392,249	44.15
2004	1,005,553	1,027,938	253,487	24.69
2005	1,080,162	1,072,607	375,850	35.04
2006	1,170,522	1,152,045	559,854	48.60
2007	1,270,137	1,238,163	413,211	33.37
2008	1,292,910	1,259,964	427,644	33.94
2009	1,372,567	1,340,206	453,928	33.87
2010	1,331,381	1,300,418	427,644	33.90
2011	1,540,141	1,505,199	579,432	38.50
2012	1,695,878	1,672,224	649,156	38.82

Source: Statistics Section, West African Examination Council (WAEC) National Office, Lagos

From table 2, the number of percentage credit passes and above in Biology continues to fall below 50% for the period of eleven years reviewed. Although grade 7 and 8 are considered to be Passes, these are not good enough for candidates who intend to gain admission into tertiary institutions. Thus, research in science education in Nigeria has continued to seek better ways of teaching biology in order to maximize meaningful learning and to identify causal variables for repeated failure (Okafor, 1993; Chikobi, 1998; Kibikiwi, 1998; Okebukola, 1998; Esiobu, 2000; Onyejegbu, 2000; Ajaja and Kpangban, 2000, Ndioho, 2007). It is in the light of these observations that this study sought to ascertain the effectiveness of the Mercedes Model with Embedded Assessment Strategy in the teaching of biology in Senior Secondary School in Lagos State. The effects of gender and subject specialisation on students' knowledge of selected Biology concepts would also be investigated.

Purpose of Study

The purpose of this study was to:

1. Investigate the effectiveness of Mercedes Model with Embedded Assessment on students' knowledge of biology concepts.
2. Examine the influence of Senior Secondary School subject specialization on students' knowledge of biology concepts.
3. Determine the extent to which gender affects students' knowledge of biology concepts.

Research Hypotheses

The following hypotheses were postulated and tested in the study at 0.05 level of significance.

1. There is no significant difference in students' knowledge of selected Biology concepts after exposure to the Mercedes Model with Embedded Assessment Strategy and in the control group.
2. There is no significant difference between science and non-science students' knowledge in the experimental and control groups.
3. There is no significant gender difference in students' knowledge of selected biology concepts in the experimental and control groups.
4. There is no significant difference in the science and non-science students' knowledge of selected biology concepts in each of the experimental and control groups.
5. There is no significant gender difference in students' knowledge of selected biology concepts in each of the experimental and control groups.
6. There is no significant difference between the science and non-science students' knowledge of selected biology concepts among those who are males and females after exposure to experimental and control groups.
7. There is no significant difference in the students' knowledge of selected biology concepts among those who are males and females in science and non-science classes exposed to the experimental and control groups.

Methodology

The study adopted a pre-test post-test control group quasi-experimental research design. The study also employed 2 x 2 x 2 factorial matrix to enable the researcher to investigate the effect of the independent and the moderating variables at the same time. This matrix is presented in Table 3.

Table 3. 2 x 2 x 2 Factorial Matrix of the Study

Treatment	Gender	Subject Specialization	
		Science	Non-Science
1	Mercedes Model with Embedded Assessment Strategy (treatment)	1. Male 2. Female	
2	Conventional Strategy (Control)	1. Male 2. Female	

Variables of the Study

The variables in this study include the independent variable which is an instructional strategy at two levels; namely Mercedes Model with Embedded Assessment Strategy in biology and Conventional Strategy in biology, the moderating variables are subject specialization (Science/Non-Science) and gender (male and female) while the dependent variables are the students' learning outcomes in knowledge of selected Biology concepts.

Population of the Study

The population of this study comprises all Senior Secondary Class II biology students in the six Education Districts of Lagos State.

Sample and Sampling Technique

From six Education Districts (EDs) in Lagos State, two were purposively selected based on the criterion that the two EDs were far away from each other to avoid the problem of contamination. Three senior secondary schools were randomly selected from each ED based on the availability of at least two graduate biology teachers, fairly well equipped biology laboratories, evidence of having presented students for the Senior Secondary Certificate Examination (SSCE) for at least five years, being a public co-educational secondary school and willingness on the part of the teachers to participate in the study. A total of six schools in the two selected EDs were involved in the study. Two intact classes (one science and another non-science) were randomly selected from each of the six schools making a total of 12 intact classes in all. Twelve biology teachers were involved in the study.

The two EDs were randomly assigned to treatment such that one was the experimental group and the other control group. Students in the Senior Secondary class II (SS II) were used in the study. The choice of SS II students was considered appropriate because these students have been exposed to some basic biological concepts and skills, which had formed an adequate background in biology for the study. Besides, these students have enough time for the experiment (teaching) since they were not preparing for any external examination. The total number of students involved in the study is 666.

Procedure

A pre-test on the chosen course content (Diffusion and Osmosis) was administered to all the students in both the experimental and control groups during the first week. Treatment Administration lasted for two weeks. The experimental group was exposed to the Mercedes Benz Model with the Embedded Assessment Strategy while the control group was exposed to the conventional strategy simultaneously. Thereafter the post-test was administered to both groups. Data collected were analysed using both descriptive and inferential statistics. The descriptive statistics include mean and standard deviation while analysis of covariance (ANCOVA) as an inferential statistics was also used. ANCOVA was utilized to control for initial differences between groups in the study i.e. pre-test before a comparison of the within groups variance and between groups variance was made. The Multiple Classification Analysis was used to present the descriptive table of the groups' performance in the study.

Results

The descriptive tables for the pre and post-test mean scores of students in knowledge based on the independent and moderating variables are as presented below:

Table 4. Pre and Post-Test Mean Scores of Students Knowledge in the Various Groups

Variable	Category	N	Pre-Knowledge	Post-Knowledge
Treatment	Mercedes Model	399	14.71	59.95
	Control	267	12.72	26.19
Subject Specialization	Science	347	17.28	51.51
	Non-Science	319	15.25	40.88
Gender	Male	405	15.23	51.16
	Female	261	13.91	46.42

Table 4 shows that students exposed to the Mercedes Model obtained a mean pre-test score of 14.71 while they obtained 59.95 at the post-test. For the control group, the mean score increased from 12.72 to 26.19. On subject specialization, science students had 17.28 and 51.51 at pre-test and post-test respectively while that of non-science students increased from 15.25 to 40.88. Also, the male students obtained 15.23 at pre-test while 51.16 is the post-test mean score in their knowledge of osmosis and diffusion. This changed from 13.91 to 46.42 at pre-test and post-test respectively in relation to the female students.

Hypotheses Testing

Table 5 presents the summary of ANCOVA results on students' knowledge.

Table 5. ANCOVA of Knowledge Scores of Students by Treatment, Subject Specialization and Gender

	Hierarchical Method				
Source of Variance	Sum of Square	df	Mean Square	F	Sig
Covariates PREKNOW	49335.665	1	49335.665	194.029	.000
Main Effects (Combined)	195032.7	3	65010.885	255.677	.000
TREATMT	168927.4	1	168927.4	664.362	.000
SUBJSPEC	24222.167	1	24222.167	95.262	.000
Gender	1883.129	1	1883.129	7.406	.007
2 Way Interactions (Combined)	14914.867	3	4971.622	19.553	.000
TREATMTx SUBJSPEC	13115.633	1	13115.633	51.582	.000
TREATMTx Gender	75.689	1	75.689	.298	.586
SUBJSPEC x Gender	1979.420	1	1979.420	7.785	.005
3 Way Interactions					
TREATMTxSUBJSPECxGender					
Model	575.204	1	575.204	2.262	.133
Residual	259858.4	8	32482.299		
Total	167055.4	657	254.270		
	426913.8	665	641.976	127.747	.000

*Significant at p<.05

Table 6. Multiple Classification Analysis of Post-Test Knowledge According to Treatment, Subject Specialization and Gender

Treatment + Category		N	Predicted Mean		Deviation		Eta	Beta
			Un-Adjusted	Adjusted for Factors and Covariates	Un-Adjusted	Adjusted for Factors and Covariates		
TREATMT	Mercmodel	399	59.9499	60.1605	13.5340	13.7446	.653	.664
	Control	267	36.1910	35.8763	−20.2249	−20.5396		
SUBJSPEC	Science	347	51.5072	52.2512	5.0913	5.8353		
	Non-Science	319	40.8777	40.0684	−5.5382	−6.3475	.210	.240
GENDER	Male	405	51.1605	47.8098	4.7446	1.3939		.069
	Female	261	39.0536	44.2529	−7.3623	−2.1630	.233	
R = .757								
R Square = .572								

• **HO1**: There is no significant difference in students' knowledge of selected Biology concepts after exposure to the Mercedes Model with Embedded Assessment Strategy and in the control group.

Table 5 shows that there is a significant effect of treatment on students' Knowledge of selected biology concepts ($F(1,657)=664.362$; $p<.05$). Hence, hypothesis 1 is rejected. This means that there is a significant difference in students' knowledge of selected biology concepts after exposure to the Mercedes Model with embedded assessment strategy than those in the control group. The MCA Table 6 further presents the respective levels of performance for the experimental and control groups. From Table 6, students in the Mercedes Model group obtained a higher knowledge mean score (= 60.16) than those in the control group (=35.88). This difference is so wide and has been found to be significant, as indicated in Table 5

• **HO2**: There is no significant difference between science and non-science students' knowledge in the experimental and control groups.

From Table 5, subject specialization has a significant effect on students' knowledge of the selected biology concepts ($F(1,657) = 95.262$; $p<.05$). Hence, hypothesis 2 is rejected.
This means that science and non-science students' knowledge of the selected concepts differ significantly after the treatment administration. Table 6 further revealed that the mean score obtained by the science students is higher (= 52.25) than that of the non-science students (= 40.07) in knowledge in the experimental and control groups.

HO3: There is no significant difference in the male and female students' knowledge in the experimental and control groups.

Table 5 showed that gender has a significant effect on students' knowledge in the experimental and control groups ($F(1,657) = 7.406$; $p<.05$). This led to the hypotheses 3a being rejected. This means that the knowledge acquired by male students is significantly different from the level acquired by the female students. Table 6 showed that the male students' knowledge rates is higher (= 47.81) than that of the female students (= 44.25).

HO4: There is no significant difference in the science and non-science students' knowledge of selected biology concepts in each of the experimental and control groups.

Table 5 showed that the 2-way interaction effect of treatment and subject specialization on students' knowledge of selected biology concepts is significant ($F(1,657) = 51.582$;$p<.05$). Hence, hypothesis 4 is rejected. The means of the interaction effects of treatment and subject specialisation showed that among the science students, those in the Mercedes Model performed better (= 73.49) in knowledge than their counterparts in the control group (= 26.96). Also, in the non-science class, the Mercedes Model group (= 48.47) performed better than the control group (= 24.95). This interaction is therefore, ordinal as the trend is similar both among the science and non-science groups of students.

HO5: There is no significant difference between the male and female students' knowledge of selected biology concepts in each of the experimental and control groups.

Table 5 showed that there is no significant interaction effect of treatment and gender on students' knowledge ($F(1,657) = 0.298$; $p>.05$).

Hence, hypothesis 5 is not rejected. The means of the interaction effects of treatment and subject specialisation showed that among the male students, the science students performed better (= 54.75) than the non-science students (= 46.05). Also, this trend is the same for the female students among whom the science students performed better (=44.59) than the non-science students (= 39.05). This is also ordinal.

HO6: There is no significant difference between the science and non-science students' knowledge of selected biology concepts among those who are males and females after exposure to the experimental and control groups.

Table 5 showed that there is no significant interaction effect of subject specialization and gender on students' knowledge ($F(1,657) = 7.785$; $p<.05$). Hence, hypothesis 6 is rejected. The means of the interaction showed that among the male students, the science students performed better (= 54.75) than the non-science students (= 46.05). Also, this trend is the same for the female students among whom the science students performed better (=44.59) than the non-science students (= 39.05). This is also ordinal.

HO7: There is no significant difference in the students' knowledge of selected biology concepts among those who are males and females in science and non-science classes exposed to the experimental and control groups.

Table 5 showed that the 3-way interaction effect of treatment, subject specialization and gender on students' knowledge is not significant ($F(1,657) = 2.262$; $p>.05$). Hence, hypothesis 7 is not rejected.

Discussion

This study revealed that there was a significant effect of the Mercedes Model with Embedded Assessment Strategy on students' knowledge of selected biology concepts. The Mercedes Model with Embedded Assessment Strategy group was significantly better in cognitive achievement mean score than the conventional groups. One logical reason for this lies in the utility of the Mercedes Model that points out three aspects of teaching for the understanding and application of knowledge: building a knowledge base, generating understanding, and finding applications. According to Gallagher (2000), one feature that resonates with teachers is that traditional practice addressed only one feature of teaching, understanding and application. Teachers have always helped students to acquire an essential base of knowledge only and have not gone beyond this point. The findings of this study are in line with Gallagher (2000), Black and William (1998b), Black and William (1998a), Bell (2000), Black and Harrison (2001), Cobern (1996).

There was a significant effect of subject specialization on students' knowledge of selected biology concepts in the experimental and control groups. Many students in the non-science class (Arts and Commercial) see biology as being forced down their throat since the SSCE regulations stipulate that they take one science subject. Hence, they have a mind-set of doing a subject that has no bearing with their choice of vocation in the near future. Consequently, they go into biology classes with a nonchalant attitude and end up not doing well. This supports Jobia's (1979) observation that difficulty in understanding generally appears to result not only in greater anxiety, but also negative feelings about the learning tasks.

Findings from this study also reveal that the effect of gender on students' knowledge is significant in favour of males. Differences between boys and girls have been established in the ways they tackle problems and answer questions. Numerous studies, among which are those of Hardin (1979) and Murphy (1982), showed that boys performed better in multiple choice test than girls, with boys being more willing to guess when they did not known an answer and girls omitting to answer such questions. This literally may explain why males did better than females in terms of knowledge but not in other dependent variables i.e. understanding and application.

On the interaction effects of treatment and subject specialization on students' knowledge the science group consistently performed better than their counterparts in the control group on each of the three dependent measures. This result is possible because the science students take one or more other science subjects, like Chemistry and Physics, in which Diffusion and Osmosis are taught in relation to permeability, solutions and matter (Friebdler, Amir & Tamir 1987).

Results from the study show that the interaction effect of treatment and gender is not significant on students' knowledge. This finding is in consistent with an analysis of gender differences in performance in science of pupils from England and Wales (Gorard et al., 2001) which shows that there are now no significant differences in attainment in science between boys and girls at both 14 + and 16+ for lower attaining pupils. However, the study looked at only the "aggregate" mark for biology, chemistry and physics.

On the other hand, in Nigeria, numerous studies on the effects of students' gender on academic achievement abound and have not produced conclusive results. Some findings indicated that significant differences exist between the performance of male and female students while other findings showed that the gender factor had no impact on students' performance. Adebayo (2002), Okeke and Ochuba (1996), Danmole (1992), Novak and Mosunola (1991), Akpan (1986), Olorundare (1989), Bank (1988) all agreed that male students have a higher level of achievement in science, technology and mathematics than their female counterparts. On the contrary, Olagunju (1998) and Obianjo (2000) reported that female students' achievement in science is higher than male students.

Findings from this study also showed that there is no significant 3-way interaction effect of treatment, subject specialization and gender on students' knowledge of the biology concepts.

Conclusion

From the findings of this study, the use of Mercedes Model with Embedded Assessment Strategy has positively improved students' knowledge of selected biology concepts (i.e. diffusion and osmosis). This strategy has taught these concepts better than the conventional strategy currently in use in most of our schools. Further, the biology students in the science class have proved their mettle better than the non-science group at imbibing the knowledge of biology concepts. In the same vein, males performed better than their female counterparts but in terms of knowledge.

Recommendations

The following recommendations, based on the findings of this study, are hereby presented for the different stakeholders of education.

1. It is very pertinent that teachers of biology should adopt the Mercedes Model with Embedded Assessment Strategy in the teaching of students in Secondary School.
2. Curriculum developers need to develop the Mercedes Model with Embedded Assessment packages for all the concepts of biology, including curricular and instructional resources, and develop tests and other measures of achievement.
3. The government should recommend the use of the strategy in the biology curriculum as well as other science subjects in the secondary schools.

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