IEEE-SEM, Volume 10, Issue 1, January-2022
ISSN 2320-9151

LEARNING HIGHER ORDER THINKING SKILLS (HOTS) IN TEACHING NON-MENDELIAN GENETICS USING BRAIN-BASED LEARNING (BBL)

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ABSTRACT

Brain-based learning (BBL) uses several teaching strategies that use information on how naturally the brain learns. It is a teaching approach that based its instructional strategies and methods on the function and structure of the brain. The study aims to determine and compare the effects of brain-based learning (BBL) and lecture-based learning (LBL) approach to learning HOTS on grade 11 STEM students in Non-Mendelian genetics. This study determined whether there was a significant difference in the pre-test, post-test and gain score performance of the BBL group and LBL group. A revised and validated questionnaire was used to compare their performances. A quasi-experimental and quantitative research design was used. Quasi-experimental was used to describe the Pretest-Posttest Control Group design. The result of the experiment showed that the pre-test performance of BBL and LBL group were not significantly different indicating comparable prior knowledge of the two groups. Pre-test and post-test performance showed that there was a significant increase in both of the performances of the group. However, the post-test performance in the BBL group was significantly higher than the LBL group. The BBL group gained higher scores than the LBL group. The students who were taught using the brain-based learning (BBL)approach significantly performed better in terms of learning higher order thinking skills compared to the students who were taught using the lecture-based learning approach. The BBL approach could significantly improve students' skills in analysing and evaluating problems on non-Mendelian Genetics.

Keywords: Brain-based learning (BBL), Higher Order Thinking Skills (HOTS), Lecture-based Learning (LBL), Non-Mendelian Genetics, Relaxed Alertness, Orchestrated Immersion, Active Processing

I. Introduction

Higher order thinking skills or HOTS which include analytical, logical, application, evaluation and synthesizing are the fundamental skills required to endure in the global market (Appana et al., 2017). One of the objectives of science education is to help learners improve their inquiry skills and monitor their progress while developing their higher order thinking ability to be globally competitive and mold them to be problem-solvers and critical thinkers (Saidoh et al., 2015). HOTS are essential for the successful development of every person - in personal and professional terms (Hadzhikolev et al., 2019).

In order to improve the HOTS of the Filipino students the Philippine government has shifted with the K-12 curriculum. This curriculum is planned and organized to meet the three different domains of science in education: understanding and applying scientific ideas and principles beyond classroom setting as well as global context; performing scientific processes using their diverse abilities and skills; and developing an aptitude towards learning new ideas while demonstrating scientific inquiry attitudes and values (DepEd, 2013). These domains are the core for developing HOTS. The new science curriculum provides students with competencies anchored on real-life situations and skills which are important in different dimensions of our society. It aims to develop scientific, logical, and environmental literate citizens who are critical and analytical thinkers and effective speakers (DepEd, 2013).

A common aim of all teachers is to upturn the retention of the long-term knowledge of learners and to develop HOTS (Halpern and Hakel, 2002). In the field of science, biology teachers have been criticized for giving numerous facts in the examination (Momsen et al., 2010). Biological science includes numerous abstract concepts which make it hard for students to learn (Anderson et al., 1990; Durmaz, 2007). In connection with this, numerous researchers have revealed that students have serious misunderstanding in topics such as genetics especially on biological inheritance. In the current age, in which genetics and biotechnology are rapidly advancing, it is important for students to mastery learn biology topics and to become science-literate individuals (Aydin and Yel, 2011).

Moreover, studies are made to come about with varied strategies and methods of teaching to enhance and develop the higher order learning of the students. One of these is brain-based learning (BBL; Gultekin and Ozden, 2008). Jonah and Uzezi (2017) defined BBL as several teaching strategies that use information on how naturally the brain learns. It is a teaching approach that based its instructional strategies and methods on the structure and functions of the brain in different aspects such as remembering, thinking, assimilating and learning (Demiril and Tufekci, 2009).

The study generally aims to determine the effects of brain-based learning in learning HOTS on grade 11 STEM students in Non-Mendelian genetics. Specifically, it aims to; a) determine the pre-test performance of students in the brain-based learning (BBL - experimental) and lecture-based learning (LBL - control) group; b) determine whether there is a significant difference in the pre-test performance of the BBL and LBL group);c) determine whether there is a significant difference in the post-test performance of the BBL and LBL group;d) determine whether there is a significant difference in the pre-test and post-test performance of the BBL and LBL group; e) determine whether there is a significant difference in the gain scores of the BBL and LBL group; f) compare post-test performance of HOTS level of the BBL and LBL group.

Background

Learning such as HOTS and memory are two closely related concepts because the brain has the ability of learning new skills, storing what was taught and reprocessing the stored knowledge (Amin and Malik, 2014). There is a need to conduct this study in order to identify and compare the LBL and BBL method in Biology class of senior high school students. The findings of this study would provide evidence on the effect of BBL on students' higher order thinking skills about the topic on non-Mendelian genetics. Furthermore, this study will challenge the higher order thinking skills of students and pedagogy strategy of teachers.

Higher Order Thinking Skills (HOTS)

Apino and Retnawati (2017) defined HOTS as the students' abilities in evaluating, synthesizing, analyzing and applying of concepts and choices for decision-making. When students come upon uncertainties, unfamiliar problems, questions, or dilemmas their skills are activated (Siraj et al., 2015). One the focal function of educational system is to teach students how to apply the knowledge of science in daily life in many contexts (Sulaiman, 2017). HOTS can be analysed and assessed through different educational frameworks and taxonomies. One of the most famous and used taxonomies to date is the Bloom's Taxonomy (Hadzhikolev et al., 2019). HOTS are on the level of analysis, application, evaluation and synthesis.

Brain-Based Learning (BBL)

BBL is a fresh idea in modelling the paradigm of education by anchoring its principles to numerous fields such as neuroscience, biology, and psychology (Corebima and Handayani, 2017). According to Caine and Caine (2002) BBL encompasses meaningful learning by recognizing the brain's encryptions to which the teaching-learning process should be adjusted to. Whilst, Jensen (1998) added that BBL is answers to what is highly effective way of learning. Moreover, Awola (2011) defined BBL as an approach that uses teaching methods and strategies based on how naturally the brain learns. Topics are organized, created and facilitated with this belief. Learning occurs as long as the brain is not hindered from its regular processes (Annakodi and Ramakrishnan, 2015).

Sousa (2004) indicated in his study that to achieve maximum learning participation and achievement, a brain-based learning approach should be introduced which includes the addition of music, movement, knowledge formation, emotions, nutrition, enriched environments, and the absence of threat. Jensen (1996) added that by providing the brain's best normal working principles BBL is attaining maximum attention, retention, understanding, and learning.

Anbazhagan and Govindarajan (2018) asserted that brain-based teaching approach enhances science subjects by providing a positive emotional climate in the classroom. This teaching approach was designed to ensure the effectiveness and efficiency of the individual learning process by designing strategies that are well-matched to the propensity, structure and optimum function of the human brain (Caine and Caine, 2003). In order to form meaningful learning, learners should be given more accountabilities for their own learning and encourage them to build connotation and connections from their schema and new knowledge (Gultekin and Ozden, 2008).

According to Caine and Caine (1990; 2002) BBL must include nutrition, movement, stress managing, and other aspects of health into the learning procedure. Furthermore, BBL focuses in creating opportunities that maximize the retention of the information taught. It considers the needs and styles of learners for evaluation and improvement of the content delivery and course format (Konecki and Schiller, 2003).

Proponents of brain-based instructional strategy (Jensen, 1998; Caine and Caine, 2002; Sousa, 2004) have identified instructional learning phases used in the teaching-learning process. Teaching and learning processes are formed in three important phases which includes relaxed alertness, orchestrated immersion, and active learning. Although these phases are not separated from each other with distinct lines, they stimulate components of each other in the process (Caine and Caine, 2002).

Relaxed Alertness

According to Caine and Caine (1995) relaxed alertness is a phase where the teachers pose a challenge to the students but with a minimum level of intimidation or threat. A secure and positive classroom atmosphere with learning activities that are challenging to the learners must be provided by the teachers (Gultekin and Ozden, 2008). Besides, Dwyer (2002) noted that when instruction becomes too explicit and lacks appropriate challenge, the learner will tune out.

Aydin (2017) also pointed out studies that demonstrate that learning is positively affected in peaceful environments while they are suppressed in fatigue and under threat environment. The situation when an experience is seen as a threat is called downshifting. Awolola (2011) pointed out that downshifting affects the frontal lobe of the brain and prevents the individual to learn and find solutions to problems. An environment should be provided in which the student will not feel threatened and receive the information comfortably. This phase consists of conducted activities that have low level of threat and high challenge and employed to bring the brain to a state of ideal learning.

In this phase students are emotionally involved and relaxed simultaneously. This happens if student feels proficient and assured and at the same time intrinsically motivated and interested with the topic discussed. According to Jack (2010) this stage sets the foundation for students to take possibilities which are important and vital in mastering skills.

Orchestrated Immersion

The key focus of this phase is for the learners to make the gist of the subject taught be meaningful and clear. Retention level will be increased if learners understand the gist of the topic through various sense organs (Materna, 2000). It is the process of interpreting information in students' minds and focusing on the content that they are confronted with. Students use local memory systems to discover the content in connection with the previous concept taught (Aydin, 2017).

Furthermore, Armstrong (2000) added that students must regularly employ the whole range of communicative media like visual arts, movement and music in order to construct meaning and remembering information. During this phase students are creating an experience requiring both a whole picture and its parts. In order to do this, teachers could use stories as well as innovative presentations, art, video clips, and music to improve learning and produce connection, entirety, and implication. According to Caine et al. (2005) when learners are offered with huge amounts of unrelated and unconnected information or when they memorize facts disconnected to the main subjects and ideas meaningful learning hardly occurs.

Active Processing

This phase includes the process of internalization of the meaningful facts by the learners (Caine and Caine, 2002). In order to achieve meaningful learning, learners should make associations to their schema and store it for the further use (Materna, 2000). It is the process of reconciliation and internalization of the information by the learner in a meaningful and conceptually appropriate way (Aydin and Yel, 2017). By actively processing the information, the learners are allowed to internalize and consolidate information (Awola, 2011).

Moreover according to Caine et al. (2005) a student's attention and retention is influenced by novelty, emotion and pattern recognition. As the brain searches for meaning, schema is connected to the new stimuli and separates unrelated information. This is called pattern recognition where there is a corresponding of novel input and idea to the schema and is one of the main features of retaining attention (Jack, 2010).

III. Materials and Methods

Research Design

A quasi-experimental and quantitative research design was used. Quasi-experimental was used to describe the pretest-posttest control group design. In the study, the control and the experimental group were given a pre-test and post-test before and after the conduct of the study.

The illustration below shows the design:

O_1	BBL	O_3
O_2		O_4

where;

O_1= BBL group pre-test
O_2 = LBL group pre-test
O_3= BBL group post-test
O_4 = LBL post-test
BBL = Brain based learning

This study was conducted at the Notre Dame of Midsayap College Senior High School department. A private school composed of diversified learners coming from different municipalities in the region. The respondents of the study were the Grade 11 senior high school students of Notre Dame of Midsayap College. The students were enrolled for the S.Y 2019-2020. They comprised of two sections with 40 students for the control group and 41 students for the experimental group. Students in these sections have comparable academic performance based on the school's entrance exam score.

Research Instrument

The research instrument that was used for the quantitative part of the study was an achievement test that was used as a pre-test and post-test questionnaire. The pre-test score of the students served as an indicator of prior knowledge and established equivalence between the two groups. The researcher constructed the questionnaire adapted and modified from several references such as Biology (Capco and Yang, 2000); Principles of Genetics (Tamarin, 2002) and Human Genetics (Lewis, 2005). The researcher used the Table of Specifications to identify higher domains and to ensure the validity of the test. A total of 40 items multiple choices was constructed and validated by three biology teachers. This was pilot tested to at least 40 students who had taken up these topics but not considered as respondents of this study. The results undergone item analysis and revision was made accordingly. Kuder-Richardson formula 20 was used to ensure the validity and reliability of the instrument was done. The final research instrument consisted of a 30 items multiple choices and served as the pre-test and post-test of both the brain-based learning (BBL) and lecture-based learning (LBL).

Sampling Procedure

Based on the utilized research design, classes were taken as intact groups without random assignments of students to each group. The two sections were heterogeneously grouped. One section had undergone the brain-based learning and the other section with lecture-based learning. A pre-test was employed to ensure that both sections have the same level of knowledge on the topic presented.

Brain-Based Learning (BBL)

After administering the pre-test in the control and experimental group, the assigned experimental group was exposed with brain-based learning while the assigned control group was exposed with lecture-based learning. BBL approach was employed following the procedure below.

I. Preliminaries: The researcher followed classroom preliminaries such as prayer, greetings, checking of attendance, setting of classroom standards and review.

II. Lesson Proper:

A. Motivation: The teacher introduced the lesson objectives to the students before they were asked to form their own group. The students were reminded that they are allowed to drink and eat.

B. Unlocking of Difficulties: The teacher defined the difficult terms that may be encounter by the students.

III. Presentation/ Discussion of the Lesson

A. Activity: Presentation of short videos to the students supplemented with short direct instruction.

B. Analysis: In their groups, the students were given sets of non-Mendelian genetics problems.

C. Abstraction: Each group was given sets of images to which the students based their non-Mendelian genetics problems.

D. Application: The images shown in the motivation part of the class was shown and the students were asked to depict the concepts in the images presented.

IV. Evaluation: Post-test was given to the students.

Lecture-based Learning (LBL)

Lecture-based learning approach was used in the instruction of non-Mendelian concepts in the control group. LBL method involves the teacher entering the class, doing the class routine, checking assignment and reviewing previous lesson. The teacher employed lecture and give the students an opportunity to do a group activity aided by PowerPoint and audio-visual presentations.

After the conduct of the teaching approaches, each student of the experimental and control group took the post-test.

Designing a BBL Approach

A week prior to grade 11 instruction, a 40-item pilot test was administered to 40 grade 12 students to validate the test items. The results undergone item analysis and revision was made accordingly. The final research instrument consisted of a 30 items multiple choices and served as the pre-test and post-test of both the brain-based learning (BBL) and lecture-based learning (LBL).

During the conduct of the experiments, all participating grade 11 students took the pre-test. The result of the pre-test was used to ensure that both of the groups have the same level of knowledge on the topic non-Mendelian genetics.

In the experimental group, brain-based learning was used. A BBL-integrated teaching learning process developed by Duman (2010) (see appendix A) and checklist from Caine (2012) (see appendix B) was adapted and modified for the study. The model denotes a learning-teaching design based on situations, procedures, and advances that are connected to each other in a corresponding manner. Three phases of BBL was applied: i. relaxed alertness, ii. orchestrated immersion, and iii. active processing in teaching non-Mendelian genetics. This teaching approach was pilot tested to other students who were not the respondents of this study prior to the actual conduct of the experiment. Feedback from the students was considered to improve the design of BBL method.

Brain-Based Learning

The classroom was set-up to fit a brain-based classroom. Projector, laptop, speaker, water jag, glass, and food were prepared by the teacher before the instruction begins. Ceiling fans and light must be fully functional also. Preliminary activities were done prior to the start of BBL approach (Appendix C). Before the actual instruction, students were asked to rearrange their chairs forming a semi-circle to let them see the board, and the slide show better. This type of seating arrangement promotes the interaction among the students. During the brain-based learning group activities, the teacher walked around the groups in the class, acting as a member of a group when it is necessary. The teacher actively joined in the teaching-learning procedure and also answered questions of the students. While the students did the group activities, a classical music was played which is available and downloaded free from YouTube (Appendix C).

Relaxed Alertness:

Under relaxed alertness: the confidence and relaxed, intrinsic motivation, awareness of emotional and the low threat, and high challenge were considered as learning-teaching process.

For the confidence and relaxed, awareness and emotional and intrinsic motivation teaching-learning process: the teacher reminded the students that they are allowed to drink and eat during the class. The students were grouped into small groups of 9 based on their choices. They were asked to take seats in which they are most comfortable. For low threat, high challenge learning-teaching process: after the students were settled, the teacher presented the objectives of the lesson and the students were asked to write down their goals on their notebook for the day's lesson. Afterwards, the teacher showed images in the PowerPoint presentation of parent and their offspring. The teacher asked the representative per group to give the observed difference between the parent and the offspring.

Orchestrated Immersion:

Under orchestrated immersion, thematic teaching, enriched environment, creative experience, creative imagination, and cooperation were considered as learning-teaching process.

For thematic teaching, the teacher showed a 2-minute video presentation available and downloaded free from YouTube (Appendix D) about non-Mendelian genetics and was supplemented by direct instruction using PowerPoint presentation. Each of the non-Mendelian principle was chunked in which after one type or concept, brain-break was applied. For creative imagination and individual experience learning-teaching process, the teacher challenged the students to create gestures and hand movements based on the definition or concept of each of the topic. The gestures and hand movements should be associated with the definition of the topics. During brain breaks, the students demonstrated the gestures for the concept taught while a classical music was played. This was done one group at a time. Brain-break lasted for 1-2 minutes per group. After all the concepts were taught, the teacher asked the students to reteach the concepts learned verbally and by using gestures and hand movements within the group.

For cooperation learning-teaching process, the students worked with their groups on problems relating to non-Mendelian genetics. The students worked as a group and were given 10 minutes to answer the problems. After that, they checked their own works.

Active Processing:

Under active processing, personal analogies and metaphor, encoding connecting, questioning and internalization teaching-learning process used.

For personal analogies and metaphor, encoding and connecting, each group were given a set of printed images that depict non-Mendelian genetics concepts. They were asked to make their own non-Mendelian genetics problems and cross them. After the activity, the students were asked to present the results they have formulated in front of the class.

For questioning and internalization learning-teaching process, the same images used in the motivation part of the lesson was shown to the students and they were asked to identify what type of inheritance is depicted in the images. The students were asked to rate if they have achieved the goals they have set at the beginning of the class.

Lecture-Based Learning (LBL)

Meanwhile**,** in the control group LBL method was used in teaching non-Mendelian genetics. Lecture-based learning method involves the teacher entering the class, doing the class routine, checking assignment, and reviewing previous lesson. The teacher employed lectures throughout the class aided by PowerPoint and audio visual presentations; the same video in the BBL group was used (Lesson plan on Appendix D). After the conduct of the teaching approaches, each student of the LBL and BBL group took the post test.

Statistical Analysis of Data

Data analysis and interpretation was done using inferential statistics. In order to attain the objectives and hypothesis of the study, parametric t-test was used.

IV. Results and Discussions

Pre-test Scores of the BBL and LBL Group

Table 1 shows the comparison of the pre-test scores of the brain-based learning (BBL) group and lecture-based learning (LBL) group where the BBL group revealed a slightly greater mean score compared with the LBL group, however, not significantly different.

Table 1. Pre-test scores of students under brain-based learning vs. lecture-based learning.

Area	*Group*	*n*	*Mean*	*Std. Deviation*	*Mean difference*	*t-value*	*df*	*p-value*
Pre-test	BBL	40	11.05	3.05	-0.25	0.358^{ns}	79	0.72
	LBL	41	10.80	3.11				

BBL- brain-based learning
LBL- lecture-based learning

Hence, at the start of the study it was established that the two groups are comparable and have the same level of HOTS on the topic non-Mendelian genetics. Scores below the 50% passing limit could also indicate difficulty in understanding concepts in non-Mendelian genetics.

Post-test Scores Result of LBL and BBL Groups

Scores of both groups showed to increase after the teaching intervention (Table 2). However, it showed that the mean score of students under the LBL group was significantly lower than those under the BBL group.

Table 2. Post-test scores of students under brain-based learning vs lecture-based learning.

Area	*Group*	*n*	*Mean*	*Std. Deviation*	*Mean difference*	*t-value*	*df*	*p-value*
Post-test	BBL	40	20.33	4.43	4.23	-4.258	79	0.00
	LBL	41	16.10	4.50				

LBL- lecture-based learning
BBL- brain-based learning

This implies that the students who were taught with the BBL approach performed better compared to students who have undertaken the LBL approach in learning HOTS.

Pre-test and Post-test Score Result and Analysis

Table 3 shows that both control and experimental groups shows significant difference between their pre-tests and post-tests scores.

Table 3. Mean difference of pre-test and post-test scores of BBL and LBL group.

Area	*Group*	*n*	*Mean*	*Std. Deviation*	*Std. Error Mean*	*t-value*	*df*	*p- value*
Pre-test /Post test	BBL	40	9.28	4.67	.740	12.55	39	0.00
Pre-test/ Post test	LBL	41	5.29	4.63	.722	-7.32	40	0.00

BBL- brain-based learning
LBL- lecture-based learning

This implies that both strategies lead to significant increase in performance. However, previous analyses revealed that the intervention (BBL) used in experimental group is far more effective than the treatment in the LBL group. Both of the groups have a two-hour schedule. In the BBL group there were more group learning activities provided for the leaners in order to make their learning more personalized. The activities used in the BBL group equates with the lecture given to the LBL group.

In this research, students' HOTS on non-Mendelian genetics were formed based on the implementation of BBL. The exposure of the students to the relaxed alertness, orchestrated immersion and active learning phases enabled them to be more relaxed and attentive attaining learning of HOTS. During the relaxed alertness phase, students were provided the opportunity to eat sweets and drink water. They were also asked to take seats in which they are most comfortable. According to Demeril and Tufecki (2009), feelings and emotions are among the principles of BBL that affects learning. BBL approach particularly improves science subjects by subjects by increasing learning through enrichment of an emotional climate in the classroom (Anbazhagan and Govindurajan, 2018).

During the orchestrated immersion phase, students were able to process information and create mental patterns by structuring and relating to the new information using gestures and cooperative discussion to find solution to problems given to them with their group mates. In the study, learning activities includes students making their own gestures related to the topic taught. In the same phase, the students were given brain breaks and a classical music was incorporated during a group activity.

In the active processing phase, students were able to process information by structuring and relating new information brainstorming, caricatures and verbal stories made by the students themselves.

According to Chinedu and Kamin (2015) developing HOTS involves doing something new with the facts, understanding them, infer from them, connect them to other facts and concepts, categorize them, manipulate them and put them together in a new or novel way. As manifested in the study, the application of different BBL learning activities used in the study has led to increased level of higher order thinking skills.

Gain Score Analysis

Table 4 suggests that the learners in the BBL group have significantly greater mean gain score than those under the LBL group. It can be interpreted that the experimental group performed better that the control group (LBL) after the intervention using BBL approach.

Table 4. Gain scores of the LBL and BBL groups.

Area	*Group*	*n*	*Mean*	*Std. Deviation*	*Mean difference*	*t-value*	*df*	*p-value*
Gain scores	BBL	40	9.28	4.67	3.98	-3.85	79	0.00*
	LBL	41	5.29	4.63				

BBL- brain-based learning
LBL- lecture-based learning

The result confirms the studies of Demeril and Tufecki (2009) which shows that the third year students at Gazi University in Turkey who have undergone BBL approach have higher achievement scores compared to students who have undergone traditional teaching in terms of developing their higher level learning. It was also revealed in the same study that brain-based learning is more effective on the higher level learning retention than the traditional teaching approach. Additionally, Annakodi and Ramakrishnan (2015) revealed in their study on grade 9 students of Avinashilingam Institute for Home Science and Higher Education for Women in India that BBL has a significant effect in fostering achievement among the students in the subject biology compared to the traditional teaching method.

Table 5 shows that on the topic non-Mendelian genetics that the BBL group has higher mean score (in percentage) compared to the LBL group. The BBL group answered (65.71%), (65.94%) and (73.13%) in the sex-linked Inheritance, codominance and incomplete dominance respectively while the LBL group were able to answer correctly (50.35%) in sex-linked inheritance concept; (50.91%) in codominance and (62.20%) in Incomplete dominance in the post-test of the same test items. The difference between the performances of each group can be attributed to the teaching strategies used in the BBL group.

Table 5. Post-test mean (in percentage) scores of the concepts of Non-Mendelian genetics between LBL and BBL groups.

Area	*Group*	*n*	*Mean (percentage)*	*Std. Deviation*	*Mean difference*	*t-value*	*df*	*p-value*
Sex-linked Inheritance	BBL	40	65.71	19.76	15.36	-3.846	79	0.000
	LBL	41	50.35	16.05				
Codominance	BBL	40	65.94	20.61	15.02	-3.409	79	0.001
	LBL	41	50.91	19.04				
Incomplete dominance	BBL	40	73.13	16.64	10.93	-2.68	79	0.009
	LBL	41	62.20	19.86				

BBL- brain-based learning
LBL- lecture-based learning

Although there was a noteworthy difference in the pre-test and post-test performances of the LBL group, it was not as high as of the performance achieved by the BBL group. In the LBL group, more than half of the class hour was spent by the teacher lecturing using PowerPoint presentation and video presentation giving the students lesser time to engage however the students were also given the opportunity to form a group and discuss unlike in the BBL group were students were given diverse activities. Keemink (2015) stated that the longer hours students spend time on lectures presses them to do off-task behaviors such as chatting and checking social media. Brandsford (2004) also added that to construct meaning constructivism must be used in which new information about the topic have to be used in representations in a variety of settings in order to reinforce and stabilize them. Lectures only partially fulfil this kind of learning. Constructivism theory is one of the bases of BBL. Since most of the science teachers still employ LBL as an approach in teaching genetics as evidenced in the low performance of the students this study provides educators innovative approach in teaching genetics.

Table 6. Post-test mean (in percentage) scores of the HOTS level between LBL and BBL groups.

Area	*Group*	*n*	*Mean (percentage)*	*Std. Deviation*	*Mean difference*	*t-value*	*df*	*p-value*
Application level	BBL	40	64.00	17.80	3.76	-0.884	79	0.379
	LBL	41	60.24	20.31				
Analysis level	BBL	40	67.32	17.78	18.71	-4.542	79	0.000*
	LBL	41	48.61	19.25				
Evaluation Level	BBL	40	75.00	17.29	20.53	-4.975	79	0.000*
	LBL	41	54.47	19.73				

BBL- brain-based learning
LBL- lecture-based learning

The table implies that of all the HOTS level in BBL group was learned compared to the LBL group. In the BBL group, the application skill of students is (64.00%) while in the LBL group is (60.24%) but not significantly, while the analysis and evaluation skills significantly increased ($p < 0.05$) is (67.32%) and (75.00%), respectively, based on the post-test performance. This can be attributed to the problem-solving and brainstorming activity given to the both groups. According to Anderson et al., (2001), brainstorming exposes students to levels of higher level thinking-application, analysis, evaluation and creating. It is a medium for creating original and useful ideas.

Evaluation skill level was highly learned. This implies that the strategies used in BBL approach are effective in learning HOTS especially on the evaluation skill level. In the BBL group, students were given the opportunity to brainstorm, solve problems, infer through make their own verbal story connected to the topic and evaluate each other's work. According to Thomas and Thorne (2009) these strategies should be incorporated in order to teach HOTS. Furthermore, Anderson et al. (2001) added that that teaching students to learn to develop evaluation techniques should comprise of activities that includes: coordinating, detecting, monitoring, testing, critiquing and judging. In the BBL group, students were given images which they evaluate according to concept the image depicted. On the whole, based on the findings obtained, it can be established that the BBL approach was more effective in learning students' conceptual HOTS as compared to the LBL method.

Based on the results of the study and the feedback gathered from the students, the BBL approach is an effective and efficient approach in learning HOTS since it sustains the attention of the students as compared to the LBL approach. BBL approach should be planned carefully since it is time-consuming but it delivers learning with impact and lasting results.

V. Summary and Conclusions

The findings of the study are summarized as follows:

1. There was no significant difference between the pre-test mean score of the control (LBL) and experimental (BBL) group.
2. There was a significant difference in the post-test mean scores of the LBL and BBL group. The BBL group has significantly higher post-test scores than the LBL group.
3. There was an increase in the post-test performance of the BBL group in term of the concepts taught compared to the LBL group.
4. BBL is effective in learning HOTS especially evaluation skills.
5. There was a significant difference between the gain mean scores of the LBL and BBL group. The BBL group has significantly higher gain scores than the LBL group.
6. There was a significant difference in the pre-test and post-test mean scores of the LBL and BBL group. However, the post-test scores of BBL group were significantly higher than the LBL group.

Conclusion

The students who were taught using the brain-based learning (BBL) approach significantly performed better in terms of learning higher order thinking skills compared to the students who were taught using the lecture-based learning (LBL) approach as shown in the results of the pre-test and post-test conducted. The BBL approach could significantly improve students' skills in analysing and evaluating problems on non-Mendelian Genetics. With the BBL approach, it helps students learn difficult topics by discussing among their group mates and by making their learning more meaningful through creating stories related to the topics learned thus, making the learning more personal. The success is also attributed to the positive climate provided to the students.

Implication

The results of the study imply that the use of BBL approach in teaching non-Mendelian genetics helps the students improve higher order thinking skills especially in improving the evaluation skills of the students. Administrators and educators can incorporate BBL in the curriculum to develop higher order thinking skills.

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Appendix

Figure 1. Diagram of BBL Integrated Learning-Teaching Process (Duman, 2010).

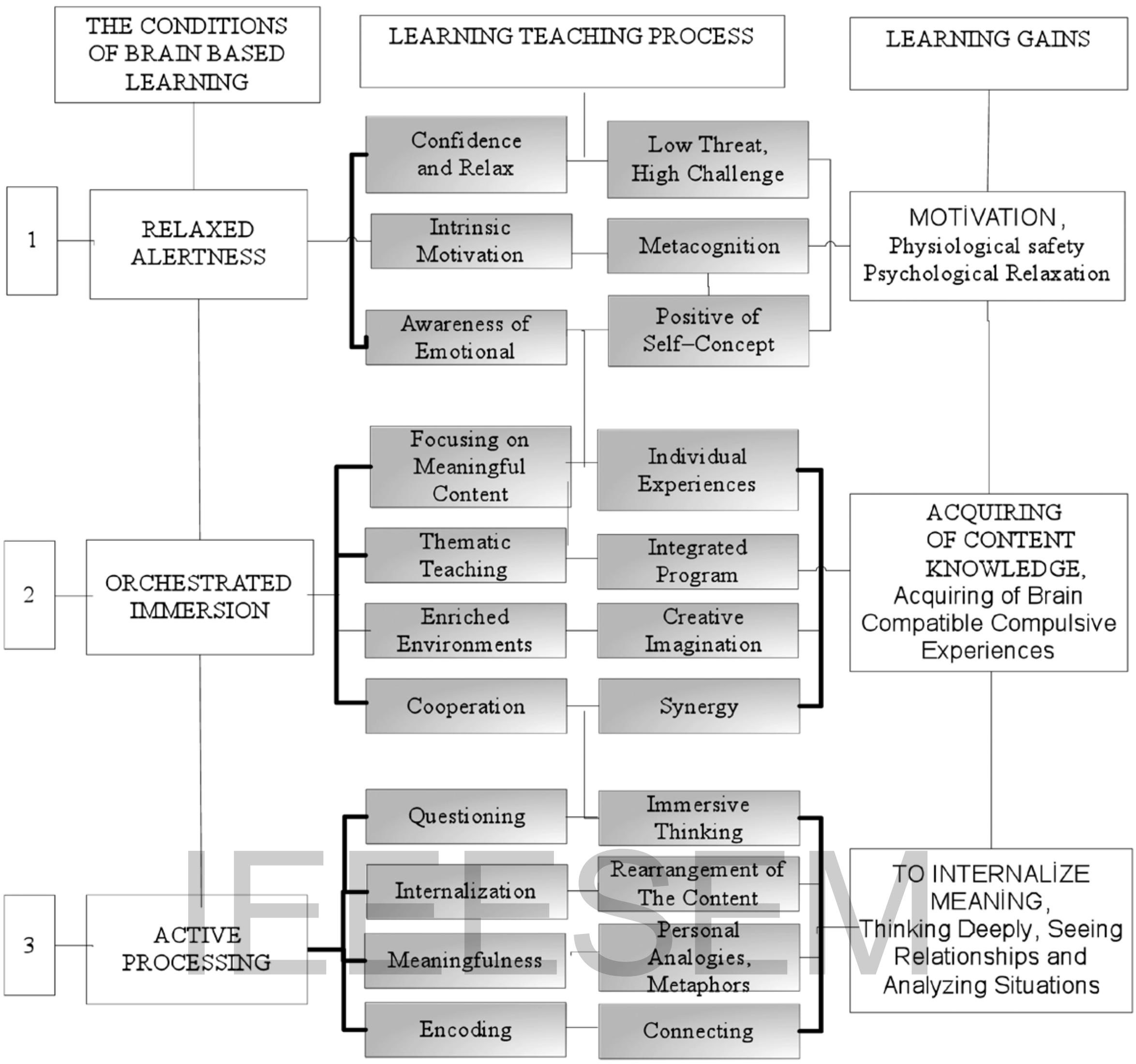

Table I. Rubric for brain-based principle in the classroom (Jack, 2010).

Relaxed Alertness	**Brain-Based Learning**	**Lecture-based Learning**
An environment that consists of low threat		

and high challenge.		
1. Do students assess their own learning?	-Students are allowed to check their group works	- Students are allowed to check their group works
2. Do students interact with one another? (projects, small groups, partners,)	-Students are grouped into small groups of five.	-Students are grouped into small groups of five.
3. Do students have time to process information?	-Students are given brain breaks after each concept are taught.	-Students spent their time listening to lecture.
4. Do students feel intrinsically motivated to learn relaxed and feel safe in the class?	-Students are allowed to eat and drink during class hours.	The only motivation for students are the pictures shown.
Orchestrated Immersion in Complex Experience		
An environment that offers multiple experiences that challenge and interest learners.		
1. Does the teacher help students understand the concept before breaking it into parts.(i.e., use stories, presentations, simulations, video).	-The teacher let the students see a video related to the topic before giving a short direct instruction.	The teacher acts as a facilitator for the group work.
2. Does the teacher provide students a multi-sensory environment? (i.e. drama, computers, hands-on experiences, writing, field trips, music, movement, art, speech)	-The teacher provides printed images, incorporated classical music, and gestures during the lecture. -Students are allowed to present their work in front of the class.	The teacher did not provide multi-sensory environment.
3. Does the teacher help students see	-Students are given the	Students were allowed to work

interconnected patterns? (i.e., discussion, projects, metaphors, analogies)	opportunities to discuss by group, answer problems and make their own analogies.	with groups but the teacher was the dispenser of knowledge.
4. Are there multiple forms of assessment? (i.e., portfolios, demonstrations, presentations, discussions, art)	-Students are given different form of assessment such as presentations and assess their own discussions.	The students were allowed to check their group activity.
Active Processing of Experience		
An environment that encourages adaptive decision making and critical thinking skills within a real-life context.		
1. Do students have opportunities to consolidate and apply information? (i.e., writing in journals, discussion groups, paraphrasing, summarizing)	-Students are grouped together and given time to discuss.	-Students are grouped together and given time to discuss.
2. Does the teacher have the students' attention? (i.e., novelty, emotion, meaning, humor, relevancy, lesson objective, games)	-The teacher use gestures and hand movements to capture the students' attention.	The teacher did not sustain the attention of the students.
3. Do students have opportunities to construct their own learning? inquiry, problem solving, journaling, feedback, predictions, debates, research)	-The students are asked to create their own non-Mendelian genetic problem from the printed images given to them.	There were no activity for the students for this phase.
4. Does the teacher address more than one learning style? (i.e. visual, auditory, kinesthetic)	- The teacher used various strategies to cater different learning style (hand gestures, visual and auditory through video presentations and	-The teacher used video presentation only.

	printed images).	