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, parametic 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.

REFERENCES

Anderson, J.R. , Reder, L.M., & Simon, H.A. (2002). Applications and misapplications of cognitive psychology to mathematics education. Carnegie Mellon University, Department of Psychology, Web site: http://act-r.psy.cmu.edu/papers/misapplied.html

Appanna, P., Kumari, S., Sulaiman, T., & Wulandari, Y. (2017). The Effectiveness of Teachers' Higher Order Thinking Skills Questions on Science Test Achievement of form Four Students. In: International Conference on Education in Muslim Society (ICEMS 2017). Atlantis Press.

Apino, E., & Retnawati, H. (2017). Developing the instructional design to improve mathematical higher order thinking skills of students. Journal of Physics: Conference series, 812 (1), 1–8. https://doi.org/10.1088/1742-6596/755/1/011001

Araghi, S. M., & Moghaddam, A. N. (2013). Brain-Based Aspects of Cognitive Learning Approaches in Second Language Learning. English Language Teaching, 6(5), 55-61

Armstrong, T. (2000). Multiple intelligences in the classroom. (2nd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.

Awolola, S. A. (2011). Effect of brain-based learning strategy on students achievement in senior secondary school mathematics in Oyo State, Nigeria. Cypriot Journal of Educational Sciences, 6(2), 91-106.

Aydin, S. & Mustafa Y. (2011). The effect of brain based learning biology education upon the academic success and attitude**.** Energy Education Science and Technology Part B: Social and Educational Studies Volume (issue) 3(1), 87-98.

Caine, R. N., & Caine, G. (1990). Understanding a brain-based approach to learning and teaching. Educational leadership, 48(2), 66-70.

Caine, R. N. & Caine, G. (2002). Reinventing schools through brain-based learning. Educational Leadership, 52, 43-47.

Chinedu, C. C., Olabiyi, O. S., & Kamin, Y. (2015). Strategies for improving higher order thinking skills in teaching and learning of design and technology education. Journal of Technical Education and Training.Vol.7

Corebima, A. D. & Handayani, B. S. (2017). Model brain based learning (BBL) and whole brain teaching (WBT) in learning.International Journal of Science and Applied Science Conference Series Vol. 1, pp. 153-161.

Duman, B. (2010). The effects of brain-based learning on the academic achievement of students with different learning styles. Educational Sciences: Theory and Practice, 10(4), 2077-2103.

Durmaz, H., & Mutlu, S. (2017). The effect of an instructional intervention on elementary students' science process skills. The Journal of Educational Research, 110(4), 433-445.

Gultekin, M. & Ozden, M. (2008). The effects of brain-based learning on academic achievement and retention of knowledge in science course. *The Electronic Journal for Research in Science & Mathematics Education*. Vol. 12, No. 1

Hadzhikolev, S., Hadzhikolev, E., & Kasakliev, N. (2019). Using Peer Assessment to Enhance Higher Order Thinking Skills. *Technology, Education, Management (TEM) Journal*. Vol. 8

Halpern, D. F., & Hakel, M. D. (2003). Applying the science of learning to the university and beyond: Teaching for long-term retention and transfer. Change: The Magazine of Higher Learning, 35(4), 36-41

Jack, C. D. (2010). Exploring brain-based instructional practices in secondary education classes. (Doctoral Dissertation). Boise State University

Jensen, E. (2000). Brain-based learning: A reality check. Educational Leadership, 57(7), 76-80.

Jensen, E. (2004). Teaching with the brain in mind. Alexandria, V.A. Association for Supervision and Curriculum Development. (1998). [20] B. Luna. Algebra and the Adolescent Brain-Trends in Cognitive Sciences, (2004), 8, 437-439.

Jensen, E. (2008). Brain-based learning: The new paradigm of teaching. Corwin Press.

Jonah, K. J. & Uzezi, J. G. (2017). Effectiveness of brain-based learning strategy on students' academic achievement, attitude, motivation and knowledge retention in electrochemistry. Journal of Education, Society and Behavioural Science, 1-13.

Keemink, L. M. Schmidt, H. G., Wagener, S. L., Smeets, G. A., & van der Molen, H. T. (2015). On the use and misuse of lectures in higher education. Health Professions Education, *1*(1), 12-18.

Konecki, L. R., & Schiller, E. (2003). Brain-Based Learning and Standards-Based Elementary Science. *Educational Resources Information (ERIC)*

Materna, L. E**.** (2000). Impact of concept-mapping upon meaningful learning and metacognition among foundation-level associate-degree nursing students. Thesis Dissertation. Colorad State University. Retrieved October 18, 2019, from http://proquest.umi.com/pqdweb?did=728371591&sid=1&Fmt=2&clientId=41947&RQT=309&VName=PQD

Momsen, J. L., Long, T. M., Wyse, S. A., & Ebert-May, D. (2010). Just the facts? Introductory undergraduate biology courses focus on low-level cognitive skills. *CBE—Life Sciences Education*, 9(4), 435-440.

Ramakrishnan, J., & Annakodi, R. (2013). Brain based learning strategies. *International Journal of Innovate and Research Studies*, 2(5).

Saido, G. M., Siraj, S., Nordin, A. B. B., & Al_Amedy, O. S. (2018). Higher order thinking skills among secondary school students in science learning. MOJES: Malaysian Online Journal of Educational Sciences, 3(3), 13-20.

Sousa, D.A. (2004). The ramifications of brain research. School Administrator Web Edition.

Sulaiman, Tajularipin, and Yuni Wulandari (2017). "The Effectiveness of Teachers' Higher Order Thinking Skills Questions on Science Test Achievement of form Four Students." *International Conference on Education in Muslim Society (ICEMS 2017)*. Atlantis Press.

Appendix

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

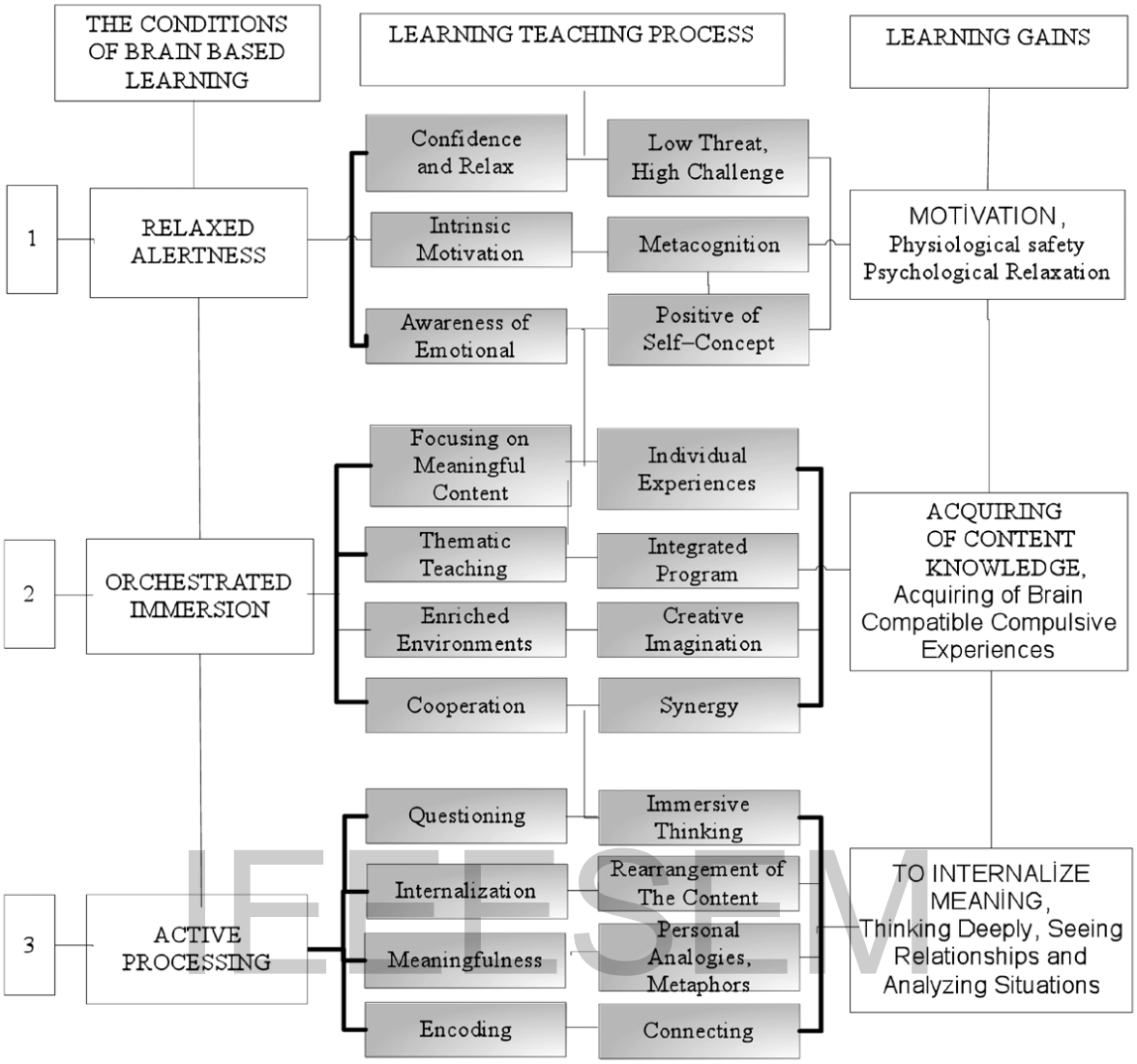

Table I. Rubric for brain-based principle in the classroom (Jack, 2010).

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).	