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ATP (Adenosine triphosphate) Quest: Board Game on Cellular Respiration for Face-to-Face and Remote Learning

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Abstract. The demand for novel way of learning complicated science concept is a constant challenge and this study addresses the issue by developing a modality that can be versatile as lesson support, supplement, and possibly a stand-alone learning delivery by letting them play and explore. The development involved three tryout and revision sequence with corresponding evaluation by experts. A usual summative assessment was given to students who have not yet taken, currently taking, and have already taken the topic. A measure of the incremental learning was measured using normalized gain, and intrinsic motivation was also measured after playing with ATP Quest. Results showed that in three types of learners, there is a good increment in their scores to the summative exam. Interestingly, there is no difference in the normalized gain for the three types of learners. Results lead the researchers to conclude that the ATP Quest can indeed engender learning even in the absence of formal instruction. That the game can be a good review for learners taking or have taken the topic. Above all, the game showed promise of applicability in remote and face-to-face learning.

Keywords: board game; normalized gain; intrinsic motivation; formal instruction.

INTRODUCTION

The 21st Century learners need a radical way of pedagogical approach as supported with the persisting learner proficiency across the curriculum but perhaps more emphasis on Science. Teaching method talks about the principles and pedagogical techniques used for classroom instruction. Educational philosophies, learners, subject areas and learning outcomes are integral parts in teaching methods. Thus, DepEd initiates the move towards utilizing learner-centered approach in teaching. Teaching methods can be teacher-centered approach or learner-centered approach. Teacher-centered approach is associated with traditional teaching, a method of teaching which focuses on the role of the teacher as the source of the learning environment and act as the main factor in such approach. This approach view students as “empty vessels”, who passively receive the

knowledge from the teachers through lectures. Learner- centered approach is associated with authentic teaching methods in which the activities focus on the learners and not on teachers. This method takes account of active learning where students solve problems, answer questions, formulate questions of their own, and other skills that involve the higher order thinking skills (Felder, 2017). In addition, this method also incorporates authentic materials in the teaching-learning process. Authentic materials are esteemed as dependable representations of the topics which can help scaffold the students' understanding about the lesson. The use of authentic materials in the classroom is a useful means to motivate learners and arouse their interests about the topic at hand (Al Azri & Al-Rashdi, 2014). Development efforts in science education evinced a shift from the conventional classroom teaching to focusing on engaging students in authentic classroom activities incorporating authentic materials in the process (Ford & Wargo, 2007).

Extensive research in a variety of disciplines has proven that play is an important factor in a child's mental development. According to Verenikina (2008), when children play games, it does not merely mirror the level of cognitive development that has been attained, but it also fuses the skills, actions, and implications that have been assimilated. Play facilitates learning because it scaffolds an expansive zone of proximal development where children are performing tasks slightly above the capacity of their abilities (Vygotsky, 1967). A study conducted by Burguillo (2010) showed that incorporating game theory with the practice of friendly competitions provides incentive for students which can help to improve their performance. Twenty-first century education is more focused on these concepts of reinforcing learning to students. These methods focus on the critical areas of a student's set of skills namely; collaboration, creativity, critical thinking and problem solving. It is becoming more evident that learners in this generation are way more different from the learners in the first decade of the new millennium. These 21st century learners are highly adaptive to changes as they have grown up in the new digital landscape. Moreover, with the advent of technology, transformation is taking place in the education system.

For the last few years, it has been observed that one of the common problems encountered by students in studying Biology is the difficulty of understanding biological concepts. Terminologies used can be very complex which need to be concretized in order to full comprehend the lesson at hand (Gutierrez, 2014). One of these biological concepts is cellular respiration. Both Patro (2008) and Baines, McVey, Rybarczyk, Thompson and Wilkins (2004) agreed that cellular respiration is a particularly difficult topic for undergraduate Science teachers and students to discuss and comprehend. Many of the students who are unfamiliar with the topic were struggling in the memorization of details and terminologies rather than focusing more on the overall process and purpose of cellular respiration.

One effective way to further comprehend the lessons would be the application of games to improve the teaching-learning process. This refers particularly to the game-based learning (GBL). Game-based learning is created to equilibrate the subject matter with the board game and the abilities of the players (learners) to retain and apply the said subject matter to the real scenarios (EdTechReview, 2013). According to studies, students learn more satisfactorily by using games in the classroom and a board game is one of the good examples. A board game was explicitly designed to foster active learning environment wherein it provides an effective means of presenting a lesson most especially for the complex ones. Board games as a medium of teaching, enables students to practice collaboration, communication and develop problem solving skills in an interactive way (Pollanen & Vartiainen, 2011). Incorporating board games in the teaching-learning process is an effective way to improve critical thinking, to develop other set of skills such as problem solving and to allow the learners to freely analyze, plan and experience things in a way that they really love. With the use of board game in teaching, students are able to develop their hands-on and heads-on skills and knowledge about the subject matter. Well-designed games can help the students in the learning process by providing an engaging, non-threatening, yet competitive environment (Palisbo et al., 2016).

The researchers themselves find this topic difficult since the terms used were highly technical and the complicated concepts need to be familiarized. The means of discussing the topic is commonly traditional where teachers simply present the lesson deductively. Furthermore, the students can only rely on their imagination about the complicated concepts and processes of the topic since it lacks hands-on activities. The researchers believe that a board game can provide a graphic representation that will help students to link information which can develop not only their lower order thinking skills but also their higher order thinking skills. Only a few studies have been made in the Philippines and in the neighboring Asian countries regarding the use of board games in teaching biological concepts. Therefore, the researchers have developed a cellular respiration board game applicable to students with wide learning background. The developed board game was evaluated and tested for its effectiveness.

METHODOLOGY

This section presents the research design, research instruments, research respondents, data-gathering procedure and data analysis.

Research Design

This study followed the one-group pre-test-posttest design. In one-group-pre-test-posttest design, each participant was tested first under the control condition and then under the treatment condition. Thus, the dependent variable in one-group-pretest-posttest research design was measured once before the treatment was implemented and once after it was implemented. (Open Text, 2017).

Research Instruments

There were four sets of instruments used in this study. One was the developed board game itself. The second set was the board game rubric (see Appendix 1). This was adapted and modified from Palisbo et al. (2016) to evaluate the developed board game in terms of content, creativity and rules and instruction. The board game rubric was modified to fit to the study. This board game rubric was validated by one (1) expert in rubric construction. The third set was the activity perception questionnaire (see Appendix 2). This was adapted and modified from Deci, Eghrari, Patrick, and Leone (1994) to measure the activity perception of the student users of the game. The questionnaire was divided into two parts. The first part has three (3) dimensions: interest/enjoyment, value/usefulness, and perceived choice. The items that belong to the interest/enjoyment dimension were item 3, 5, 8, 10 and 14. The items that belong to the value/usefulness dimension were item 1, 4, 6, 9, 11, 12, 13 and 15. The items that belong to the perceived choice dimension were 2 and 7. The second part was intended to collect information from the student users that would help the researchers improve the developed board game. The fourth set of instruments was the researchers- made test to be administered before and after the topic was covered by the experimental group to determine the performance level of the students in Cellular Respiration in the pretest and posttest (see Appendix 3). This researchers-made test was validated by two (2) content experts in the field of Biology, one (1) expert in test construction, and one (1) expert in English grammar. The researchers developed a board game based on the famous game MonopolyTM. The game can be played by 3-5 players or 3-5 groups with a maximum of 5 members per group. A student would be assigned to be the moderator of the game. The players of the game would select a token of their choice and place their tokens on the corner marked “GO”. Each player would take turns in throwing the dice and the player with the highest total starts the play (Player 1), the next highest would be the second (Player 2), and so on.

To start the game, Player 1 would roll the dice and move his or her token to the corresponding box. Player 1 would follow the instruction corresponding the box. After Player 1’s turn, Player 2’s turn would come next, and so on. When a player lands in a Question box, the player would have to pick one question card under the category

indicated, read the question out loud, and answer the question given. If the player answered the question correctly, then the player would get the corresponding reward indicated in the card. A player can only steal the questions of other players if and only if the player has a Steal Chance card which can be obtained from drawing cards from the Test Your Luck cards. If ever there are more than one (1) player who wants to steal the question, they need to roll the dice and the player with the highest total would be the first one to steal the question. If the first player to steal the question cannot answer it, then the second player with the second highest total can have the chance to steal the question. Only two (2) players are allowed to steal the same Question card. If no one got the correct answer, the moderator would be the one to reveal the answer to the question. Only questions from Little Brain Exercise question box, Vigorous Brain Exercise question box, and Extreme Brain Exercise question box can be stolen, except for the True or False questions.

In answering the questions, the players would be given a maximum time of 5 seconds for answering the Little Brain Exercise questions and would be given 2 ATPs if they could answer the question correctly. For Vigorous Brain Exercise questions, the players would be given 10 seconds to answer and 3 ATPs and 1 NADH as the corresponding points. For Extreme Brain Exercise questions, the players would be given 20 seconds to answer and 5 ATPs, 1 NADH and 1 FADH as the corresponding points (see Appendix E).

For questions from Test Your Luck cards, when a player lands in Test Your Luck box, the player would pick one (1) Test Your Luck card and follow the instructions written in the card. If the player would pick a question in Test Your Luck cards, the player would have the chance to receive 5 ATPs, 1 NADH and 1 FADH as the rewards by answering the question correctly. The questions would vary in terms of difficulty. The player can choose to decline the offer of the question from the Test Your Luck card and if ever the player would decline the offer or is unable to answer the question correctly, the other players will have the opportunity to steal the question.

When a player lands in a landmark, which can be the mitochondrion or the cytoplasm, the player can trade his or her rewards in the said landmark with the corresponding amount of ATP that they can be exchanged with. When a player lands in the Lack of Oxygen box, the player would lose a turn and would have to give up one (1) ATP. As a player lands in the Drop by in the Matrix box and in the Just Visiting box, the player would do nothing and wait for their next turn. As a player passes by the box marked GO, the player would collect free two (2) ATPs. The teacher can set a time limit for the duration of the game, for instance having the game for only 20 minutes or so. The player who garners the most number of ATPs or the first to collect 36 ATPs wins the game. If ever there would be a tie, both players and groups would be declared as winners. The board game rubric employed a 4-point scale with four (4) being the highest.

2.3 *Research Respondents*

The research participants are the students from La Salle University-Night High School (LSU-NHS) during their fourth grading period and college students enrolled in Biological Science (NS103) classes of the second quarter lessons in the second semester of Academic Year 2017-2018 as indicated in the course outline provided by the Science Department of the College of Arts and Sciences. There are twenty-seven (27) students from NS10301 class, thirty (30) students from NS10302 class and twenty (20) students from NS10303. There are thirty-five (35) students coming from grade 7-Br. Bernadine, thirty-five (35) students from grade 8-Br. Andrew, forty-one (41) students from grade 9-Br. Crisanto and twenty-seven (27) students from grade10-Br. Edward from LSU-NHS. The total number of student participants was two hundred fifteen (215). The participants in each section were divided into 2 groups, each group consists of 4 subgroups consisting approximately of 2-6 participants each. To determine the participants of each group, random sampling by lottery was employed.

Data-Gathering Procedure

The researchers administered a pretest and posttest to each class. The pretest was given first to each class, after which, the researchers let each class to play the developed-board game. The participants in each section were divided into 2 groups, each group consists of 4 subgroups consisting approximately of 2-6 participants each. To determine the participants of each group, random sampling by lottery was employed and the researchers discussed the mechanics of the game.

While playing, it was very evident that all the student-participants in all classes were very participative, they're attentions were on the game when the game started and by the time the game ends thus, the participants were motivated. They always celebrate if ever they could answer the questions correctly through yelling and clapping their hands. It was very evident that all the participants really enjoyed the game and even the facilitators enjoyed the game as well.

After playing, posttest was given to each class, and then the activity perception questionnaire was given and followed by the rubric of the board game. This were checked and recorded for data analysis.

Data Analysis

Statistical tools were used to analyze the data with normalized gain which is used to measure the effectiveness of a course in promoting conceptual understanding (Hake, 1998), McNemar's test, a test on a 2x2 classification table used to test the difference between paired proportions, e.g. studies with "before and after" design (MEDCALC, 2018) and one-way ANOVA which used to determine whether there are any statistically significant differences between the means of three or more independent (unrelated) groups (Lund Research Ltd, 2013).

Thus, statistical analyses were carried out towards the success of this study. These includes McNemar's test, used to measure the effect of the developed-board game to the pretest and posttest performance of the students. Normalized gain was used to measure the effectiveness of the researchers-developed board game in promoting conceptual understanding of the topic cellular respiration for a consistent analysis over diverse student population with widely varying initial knowledge states and one-way ANOVA was then used to determine the significant difference in the normalized gains.

The researchers made fair and equitable judgments by ensuring accurate results on each statistical tool mentioned. This helped the researchers in determining the effectiveness of educational board game as a stand-alone material for cellular respiration.

RESULTS AND DISCUDDION

The result from the achievement test conducted by the researchers before and after the application of the board game which was participated by 215 students from LSU-Night High School and college students enrolled in NS103 (Biological Sciences) classes and results from the board game rubric and the Activity Perception Questionnaire answered by the participants after the game are shown in the following table.

Performance level of the students in cellular respiration and normalized gain.

The researchers sought to know the performance level of the students in cellular respiration and if there is a significant difference between the normalized gain of each group of students.

Table 1 Average Performance and Normalized Gain of Each Section of Students (N=215)

Section	Average Pretest Scores	Average Posttest Scores	Average Normalized gain
Grade 7 (N=35)	5.943	7.343	0.075
Grade 8 (N=35)	5.314	7.886	0.163

Section	Average Pretest Scores	Average Posttest Scores	Average Normalized gain
Grade 9 (N=41)	7.878	9.927	0.159
Grade 10 (N=27)	6.556	8.000	0.096
NS10301 (N=27)	6.667	9.815	0.218
NS10302 (N=30)	6.433	8.700	0.150
NS10303 (N=20)	6.800	8.800	0.135
Overall Mean	6.513	8.639	0.142

Table 1 shows the data results on the average performance level of the students in cellular respiration based on their pretest and posttest scores and its normalized gain. The students' average pretest and posttest scores are satisfactory at 6.513 (~7) and 8.639 (~9) respectively. Results show that the scores of the students increased when the average pretest scores are compared with the average posttest scores. This indicates that the board game is successful in improving the performance level of the students in cellular respiration. To test whether there is a significant difference among the normalized gain of each section, one-way ANOVA was used. At alpha level 0.05, the test showed that the P-value is 0.06478 indicating that there is no significant difference in the normalized gain among sections. The normalized gain between the four different grade levels from LSU-Night High School, and three sections from NS103 did not differ much from each other which is an indicator of a similar effect across grade levels with or without prior formal instruction. The results of the study are similar to the study conducted by Gauthier, Corrin and Jenkinson (2015) where they explored the influence of game design on learning. They suggested that game mechanics can encourage more specific problem-solving strategies than having only a study aid, leading to greater predictability of learning outcomes. Studies conducted independently by Viray (2016) and Jui-Mei, Chun-Ming, Hwang and Yueh-Chiao (2011) both revealed that the academic performance of students increased after being exposed to the board game. The results in the achievement test was in fact very low and that would entail revisiting the items, but the good side of the result is that the performance is the same for respondents whether they have taken the topic already or not. This implies that a board game has the capacity to impart learning, and this needs to be investigated further in the same topic, in other topics, and in other subject areas be it Science or not. There is also an interesting aspect as to what best mode the board game be used, as instructional tool, as review tool, or as standalone learning material like DIY.

Comparison of the pretest and posttest scores of the students per item.

One of the purposes of the study is to know if there is a significant difference between the pretest and posttest scores of the students per item in the achievement test. Table 2 presents the results below.

Table 2 Significant Difference between the Pretest and Posttest Scores of the Students per item

Item Number	Wrong before Wrong after	Right before Wrong After	Wrong before Right after	Right before Right after	P-value	Decision
1	139	3	58	15	<0.000001	Statistically significant
2	54	22	78	61	<0.000001	Statistically significant
3	34	15	80	86	<0.000001	Statistically significant
4	46	23	59	87	0.000087	Statistically significant
5	112	32	45	26	0.171061	Not statistically significant
6	72	24	53	66	0.001263	Statistically significant

Item Number	Wrong before Wrong after	Right before Wrong After	Wrong before Right after	Right before Right after	P-value	Decision
7	50	36	22	107	0.086949	Not statistically significant
8	82	31	61	41	0.002315	Statistically significant
9	67	32	80	36	0.000007	Statistically significant
10	121	35	42	17	0.494382	Not statistically significant
11	118	24	49	24	0.004626	Statistically significant
12	148	25	27	15	0.889884	Not statistically significant
13	94	39	57	25	0.082193	Not statistically significant
14	109	25	58	23	0.000378	Statistically significant
15	87	33	50	45	0.078420	Not statistically significant
16	69	33	71	42	0.000247	Statistically significant
17	83	44	36	52	0.434042	Not statistically significant
18	164	14	29	8	0.031539	Statistically significant
19	122	29	30	34	1.000000	Not statistically significant
20	116	40	34	25	0.561381	Not statistically significant

Table 2 shows the data recorded when the pretest and posttest of each student for each item was compared. McNemar's test was used to test whether there is a significant difference between the scores from the pretest and posttest scores of the students in each item after the application of the board game. The test showed that at alpha level 0.05, 55% of the test items have statistically significant difference while 45% of the test items has no significant difference between the pretest and posttest scores. Results suggest that after the application of the board game, by comparing the paired nominal data of the pretest and posttest, the students correctly answered many of the items after playing the board game. This implies that they have learned something after playing the board game. Just like in the study conducted by Palisbo et al. (2016), which supports that a board game has the capacity to enhance cognitive understanding about topics even without formal instruction.

Intrinsic motivation of the students after using the board game

One of the purposes of the study is to know the intrinsic motivation of the students after using the board game. Students were asked to respond on an activity perception questionnaire with a 7-point Likert scale. Table 3 presents the results.

Table 3 Average Intrinsic Motivation of the Students in Playing the Board Game (N=215)

Section	Value/ Usefulness	Interest/ Enjoyment	Perceived Choice
Grade 7	6.118	6.314	6.229
Grade 8	6.555	6.703	6.476
Grade 9	6.364	6.548	6.214
Grade 10	6.373	6.767	6.629
NS10301	6.363	6.631	6.423
NS10302	6.271	6.640	6.300
NS10303	5.764	6.310	6.283
Overall Mean	6.258	6.559	6.365

Table 3 shows the data results on the perception of the student participants to the board game activity in terms of the dimensions Value/Usefulness, Interest/Enjoyment, and Perceived Choice. Activity perception questionnaire is the measure of intrinsic motivation as respondents played the board game "ATP Quest." The questionnaire is a 7- point Likert scale and it turns out that the respondents have very high motivation. First is the dimension of Interest/Enjoyment with overall mean of 6.559. This element of enjoyment is crucial for learner to engage further in an endeavor in science (Ainley & Ainley, 2011; Bye,

Pushkar & Conway, 2007). Thus, if the board game enhances enjoyment, then learners will be interested to work on the material.

The next dimension is Perceived Choice with overall mean of 6.365, and this is identified as one of the general motivational constructs suspected as potential mediators towards conceptual change (Pintrich, Marx & Boyle, 1993). In this case, the board game contained this element of perceived choice that has something to do with control in the activity and can lead to the desired conceptual change that is learning.

The last dimension is the Value/Usefulness with overall mean of 6.258 which is identified as crucial stimulator for learners to continue pursuing a task (Chiu & Wang, 2008; Al Azri & Al-Rashdi, 2014).

The average of the overall mean of each dimension is 6.394 which means that the students perceived the board game activity as very interesting, useful and helpful in recalling and understanding the terms in the topic cellular respiration.

On the part 2 of the activity perception questionnaire, students were asked to answer two questions about their experience in using the board game. Students have left positive comments about the board game activity. Some students remarked that one of the best features of the game was that it can enhance self-focus, concentration and help them have a deeper understanding about the topic. A student stated that the game helped them develop their critical thinking skills and collaborative skills improving their teamwork. Other students said that they liked the questions in the game, especially the True or False questions, the most as it is comprehensive, and it really made them think about what they have previously learned about the topic and relate what they have already learned in order to answer the questions thrown at them helping them also to recall and remember their learnings from the past. The questions are also a bit challenging and they like that aspect of it. Many of the students commented that the best feature of the game was that it was fun and interesting to do. A student loved the experience because they are learning and at the same time, they are also having fun. A student also commented that the board game was somewhat new to her making the whole experience even more exciting.

Students also commented on the parts of the board game that needed improvement. Some mentioned that some of the questions, especially for the "Extreme Brain Exercise" questions, are very hard for them and that they cannot answer it. A student remarked that the time given for the whole duration of the game should be extended. Others mentioned about some parts of the mechanics that they wanted to be enhanced like the mechanics regarding the steal cards. Some stated that the tokens and the materials being used for the board game, like the quality of the chips for ATP, NADH and FADH2, need to be improved.

Perception of the students to the board game

One of the purposes of the study is to know the perception of the students to the board game in terms of its content, creativity, and rules and instruction. Students were asked to respond on a board game rubric. Table 4 presents the results.

Table 4. Perception of the Students on the Board Game based on Content, Creativity, and Rules and Instruction (N=215)

Section	Content	Creativity	Rules and Instruction
Grade 7	3.722	3.833	3.639
Grade 8	3.771	3.886	3.686
Grade 9	3.857	3.809	3.667
Grade 10	3.944	3.722	3.667
NS10301	3.846	3.808	3.577
NS10302	3.900	3.900	3.700
NS10303	3.650	3.650	3.450

Section	Content	Creativity	Rules and Instruction
Overall Mean	3.813	3.801	3.626

Table 4 shows the data results of students' perception on the board game based on content, creativity, and rules and instruction. Rubric was adapted and modified from Palisbo et al. (2016) to evaluate the developed board game in terms of content, creativity and rules and instruction. The board game rubric was modified to fit to the study. Based on the results, the participants perceived the board game as excellent in all three criteria. First is the content with overall mean of 3.813. This criterion is crucial for learner to engage further in an endeavor in science (Ainley & Ainley, 2011; Bye, Pushkar & Conway, 2007). Thus, if the board game enhances the knowledge of the students about the said topic, then learners will be interested to engage on the material.

The next criterion is creativity with the overall mean of 3.801. The rubric assessed the participants' perception of the creativity of the developed-board game about cellular respiration based upon the components described by Bisson and Luckner (1996). In this case, the board game contained these elements of art that have something to do with the principles of design applied to the board game, the construction of mechanics and the questions as well. Exposing students to such language forms will enable them to cope with genuine interaction, whether it is inside or outside the classroom (Widdowson,1990).

The last criterion is rules and instruction with an overall mean of 3.626 which is identified as crucial part of the board game as it indicates how the game will be played, if the rules and instruction are clear and very easy to follow. The average of the overall mean of each criterion is 3.746 which means that the students perceived the board game as an excellent board game in terms of content, creativity and rules and instruction.

Conclusions and Recommendations

The purpose of the study was to develop a board game applicable to students with wide learning background and assess its effectiveness as a stand-alone material in learning the topic cellular respiration.

1. The performance level of the students in cellular respiration in the pretest and posttest are both satisfactory having an overall mean of 6.513 (~7) and 8.639 (~9) respectively.

2. The average posttest scores ($\bar{x}$= 8.639) of the students are higher in comparison to their pretest scores ($\bar{x}$= 6.513).

3. One-way ANOVA showed that there is no significant difference among the normalized gain of each sections, having a P-value of 0.06478.

4. McNemar's Test revealed that 55% of the test items have statistically significant difference while the remaining 45% of the items have no statistically significant difference between the pretest and posttest scores.

5. The students' intrinsic motivation after using the board game is very high, with each dimension namely value/usefulness, interest/enjoyment and perceived choice having an overall mean of 6.258, 6.559 and 6.365 respectively.

6. The perception of the students to the board game in terms of content ($\bar{x}$ = 3.813), creativity ($\bar{x}$= 3.801), and rules and instruction ($\bar{x}$= 3.626) is excellent.

Based on the findings of the data gathered, the researchers conclude that the developed board game was effective in a sense that the performance level of the students has improved as shown in their higher posttest scores. From that academic improvement, students are more motivated to learn as they engage in the board game. Hence, it is through the developed board game that captivates students' attention in learning the topic cellular respiration in a relaxed and fun environment.

Considering the conclusions of this study, the following points are hereby recommended:

1. Addition of card game as preliminary game - The use of card game is to unlock difficult terms that the student would encounter during the game. Thus, the cards

will contain terms, definition and explanation; this would give the learners background knowledge.

2. More groups or players - The game must accommodate a large number of participants who want to play the game. In order to address the problem, the researchers would like to add more question boxes varying in difficulty.

3 . Lesson sequence with the developed board game as instructional support - The researcher would like to utilize the developed game as instructional material where it can be used as an activity in teaching Cellular Respiration or used as an assessment tool.

4. Student as the moderator of the game - Instead of having the teacher to be the moderator of the game, students should take the role as the moderator of the game. They are the ones taking control in giving the ATP, NADH, FADH, and act as the timekeeper as well to give emphasis that the developed game can be utilized as a stand-alone game that can be played even without formal instruction coming from the teacher.

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Appendix 1

BOARD GAME RUBRIC

This is the board game rubric adapted and modified from the work of Palisbo et al. (2016).

	Fair 1	Good 2	Very Good 3	Excellent 4	
Content	No factual information about cellular respiration is presented.	1-5 factual information about cellular respiration is presented.	6-10 factual information about cellular respiration is presented and factual.	All relevant information about cellular respiration is presented and factual.	
Creativity	The board game does not follow the principles of design, has mechanics and contains unnecessary questions.	The board game follows 1 or 2 of the principles of design, has innovative mechanics but contains unnecessary questions.	The board game follows 3 or 4 of the principles of design, has innovative mechanics and interesting questions.	The board game follows all the principles of design, innovative mechanics and interesting questions.	
Rules and Instructions	The rules and instruction provided are confusing and hard to follow.	The rules and instruction provided are a little bit confusing.	The rules and instruction provided are easy to follow.	The rules and instruction are very clear and very easy to follow.	
				Total	

Appendix 2

ACTIVITY PERCEPTION QUESTIONNAIRE

Congratulations, you have tried using the board game. Hence, the researchers would like to ask your experience from the task. This questionnaire is divided into two parts. Part 1 deals with the following items concerning your experience with the task. Part 2 is intended to collect information from the student users that will help the researchers improve the developed board game. Please answer all items. For each item in Part 1, please indicate how true the statement is for you using the following scale as a guide.

Part 1

1	2	3	4	5	6	7
not at all true			somewhat true			very true

1. I believe that doing this board game activity could be useful in understanding the concepts and terms in Cellular Respiration.
2. It is my choice to participate in this board game activity.
3. While I was doing this board game activity, I enjoyed it.
4. I believe that doing this board game activity is useful in improving concentration.
5. This board game activity was fun to do.
6. This board game activity is important for a Biological Sciences student like me.
7. I participated in this board game activity because I wanted to.
8. This board game activity was very boring.
9. This board game activity could improve my study habits.
10. This board game activity was very interesting.
11. I believe doing this board game activity could be beneficial for me.
12. I believe doing this board game activity could help me do better in school.
13. I would describe this board game activity as very comprehensive.
14. This board game activity was challenging to do.
15. I would be willing to do this board game activity again.

Part 2

1. What are the best features of the board game activity?

_____
_____.

2. What are the parts of the board game that need to be improved? How can it be improved?

_____
_____.

Appendix 3

TEST QUESTIONNAIRE

MULTIPLE CHOICE TEST

Directions: Read the questions carefully. Choose and encrice the letter of the best answer.

1. What is the terminal electron acceptor in the electron transport chain?
   A. ATP C. NAD
   B. Carbon dioxide D. Oxygen

2. In which organelle does aerobic respiration occur?
   A. Amyloplast C. Mitochondrion
   B. Chloroplast D. Nucleus

3. What is the net production of ATP from one glucose molecule through aerobic respiration?
   A. 2 C. 36
   B. 32 D. 38

4. What is the energy currency of all cells?
   A. ATP C. GTP
   B. $FADH_2$ D. NADH

5. The Krebs Cycle will generate
   A. 10 NADH & 4 $FADH_2$ C. 10 NADH & 2 $FADH_2$
   B. 8 NADH & 4 $FADH_2$ D. 8 NADH & 2 $FADH_2$

6. How many ATP molecules are produced for each glucose molecule used in fermentation?
   A. 2 C. 6
   B. 4 D. 10

7. Which of the following is formed during glycolysis?
   A. Citric Acid C. Glucose 6-phosphate
   B. Fumarate D. Oxaloacetate

8. In electron transport chain, how many ATP does a molecule of NADH produce?
   A. 3 C. 1
   B. 4 D. 5

9. What do you call the series of anaerobic chemical reactions in the cytoplasm that break down glucose into pyruvic acid forming a net profit of two ATP molecules?
   A. Calvin cycle C. Glycolysis
   B. Carbon-dioxide conversion stage D. Krebs cycle

10. What is the by-product of cellular respiration?
    A. ATP C. Oxygen
    B. Glucose D. Carbon dioxide

11. Where does the process of glycolysis start and end?
    A. Cytoplasm
    B. Mitochondrion
    C. Nucleus
    D. Plasma Membrane
12. What do you call the metabolic pathways that involve the breakdown of complex molecules to simpler compounds?
    A. Anabolism
    B. Catabolism
    C. Electron Transport Chain
    D. Krebs cycle
13. Which metabolic pathway is common to both fermentation and cellular respiration?
    A. Electron Transport Chain
    B. Glycolysis
    C. Krebs cycle
    D. Photosynthesis

14. What are the molecules being produced in glycolysis?
    A. Glucose, carbon-dioxide & water & pyruvate
    B. ATP, NADH & pyruvate
    C. ATP, glyceraldehyde-3-phosphate
    D. Pyruvate, glyceraldehyde-3-phosphate & water

15. The fermentation pathways produce no more ATP beyond the small yield from Glycolysis and the remaining reactions
    A. regenerate ATP
    B. regenerate NAD+
    C. dump electrons on an inorganic substance
    D. dump ions on an inorganic substance
16. What is the product of anaerobic respiration that may result to muscle fatigue by accumulation?
    A. Alcohol
    B. Ethanol
    C. Lactic Acid
    D. Pyruvate

17. ATP can be formed through substrate-level phosphorylation and this process requires
    A. an input of energy
    B. a high-energy phosphate group that is transferred directly to ADP
    C. a concentration gradient of protons
    D. the protein ATP synthase

18. The final output of the Krebs cycle include the following EXCEPT
    A. NAD^+
    B. $FADH_2$
    C. ATP
    D. CO_2

19. Which of the following is the key intermediate compound linking glycolysis to the Krebs cycle?
    A. ATP
    B. Acetyl CoA
    C. Malic Acid
    D. Pyruvic Acid

20. What happens during the process of oxidative phosphorylation?
    A. A high concentration of electrons is built up in the intermembrane space
    B. A high concentration of protons is built up in the mitochondrial matrix
    C. A high concentration of protons is built up in the intermembrane space
    D. A high concentration of electrons is built up in the mitochondrial matrix

Appendix 4

MECHANICS OF THE "ATP QUEST" BOARD GAME

1. This game will need **3-5 players.** This game can also be played by **3-5 pairs of players.**
2. Before the start of the game, there should be an assigned moderator for the game. It should not be one of the players of the game.
3. First, each player will select a token of his/her choice. All the players will place their tokens on the corner marked "GO".
4. Next, each player will take turns in throwing the dice. The player with the highest total starts the play *(Player 1)*, the next highest will be the second *(Player 2)*, and so on.
5. To start the game, Player 1 will roll the dice and move his/her token to the corresponding box. Player 1 will follow the instructions written on the box. After Player 1's turn, Player 2's turn will come next, and so on.
6. When a player lands in a ***Question Box***, he/she will have to pick one question under the category indicated in the box and **read the question and and his/her answer OUT LOUD.** If the player answered the question correctly, then he/she will get the corresponding ATP, NADH, $FADH_2$ and/or letter/s indicated in the *question card*. Otherwise, the player will not get any of the said rewards and the other players will have the opportunity to steal the question and get the said rewards.
7. The player who wants to steal the question needs to **BET 1 ATP**. If ever there are more than 1 player who want to steal the question, they need to roll the dice and the player with the highest total will be the first one to try to steal the question and if the first player was not able to answer the question correctly then the second player with the second highest total will have the chance to answer the question and so on.
8. **ONLY** questions from *"Vigorous Brain Exercise" and* for "*Extreme Brain Exercise" question box* can be stealed.
9. In answering the questions, the players will be given a maximum time of **5 seconds** for *"Little Brain Exercise" question box*, **15 seconds** for *"Vigorous Brain Exercise" question box*, **20 seconds** for "*Extreme Brain Exercise" question box* and for *"question chance card"* as well.
10. The letter/s got from the *question cards* can be collected by the player in order to form **NADH** and **$FADH_2$** which can then be exchanged for ATP when he/she lands on a landmark.
11. When a player lands in a landmark, which can be the ***Mitochondrion*** or ***Cytoplasm***, he/she can trade/exchange his/her *NADH* and/or *$FADH_2$* in the said landmark with the corresponding amount of ATP that they can be exchanged with.
12. When a player lands in ***Chance***, he/she will pick *one chance card* and follow the instruction written in the card.
13. For ***Question Chance Cards***, if the player was able to picked a ***Question Chance Card***, he/she will have the chance to receive rewards by answering the question correctly **BUT** the player will be asked to **GIVE UP 1 ATP** in order to access the *question chance card.* The questions will vary in terms of difficulty. The player can chose to decline the offer of the *questions chance card* and the other players will have the chance to steal the *question chance card* if the player will decline thhe offer or unable to answer the question correctly.
14. The players who want steal the question will be asked to **BET 1 ATP.** If ever there are more than 1 player who want to steal the question, they need to roll the dice and the player with the highest total will be the first one to try to steal the question and if the first player was not able to answer the question correctly then the second player with the second highest total will have the chance to answer the question and so on.
15. When a player lands in the ***Jail***, he/she will lose a turn and will have to give up one ATP.

16. As a player passes by **GO**, he/she will collect two (2) free ATP.
17. As a player lands in the ***Drop by in the park*** and in the ***Just Visiting*** as well**,** he/she will do nothing.
18. *The game will **END** if one player has collected **36 ATP**.*

Appendix 5

"ATP QUEST" SCORE BOARD

QUESTIONS	POINTS
Little Brain Exercise Questions	2 ATPs
Vigorous Brain Exercise Questions	3 ATPs and 1 NADH
Extreme Brain Exercise Questions	5 ATPs, 1 NADH and 1 FADH
Test your Luck Questions	5 ATPs, 1 NADH and 1 FADH

BOXES	POINTS	EQUIVALENT ATP POINTS
CYTOPLASM	1 NADH	2 ATPs
	1 FADH	0 ATP
MITOCHONDRION	1 NADH	3 ATPs
	1 FADH	2 ATPs

Appendix 6

"LITTLE BRAIN EXERCISE" QUESTIONS

1. What is the chemical formula for carbon dioxide?
2. How many carbons dioxide are produced by the Krebs cycle to each molecule of glucose?
3. Who discovered the Citric Acid Cycle?
4. What are the final outputs of the Krebs cycle?
5. How many molecules of NADH are produced in Krebs cycle per molecule of glucose?
6. What are the three main biochemical pathways of cellular respiration?
7. What are the by-products of cellular respiration?
8. What does the suffix "-lysis" mean?
9. What is the chemical formula for glucose?
10. What is the ultimate electron acceptor in aerobic respiration?
11. How many water molecules are produced in the cellular respiration to each molecule of glucose?
12. It is sometimes called the "powerhouse" of the cell.
13. What is the enzyme protein that synthesizes ATP?
14. What stages of the cellular respiration occur in the mitochondria?
15. Which of the process of cellular respiration does not require oxygen to function?
16. How many carbons are in glucose?
17. How many molecules of carbon dioxide would be produced by five turns of the Krebs cycle?
18. What is the net ATP yield from a molecule of glucose for eukaryotic cells?
19. In what cell structure does anaerobic cellular respiration take place?
20. What are the two types of fermentation?
21. What is the process of converting glucose into energy?
22. How many molecules of NADH are formed during glycolysis per molecule of glucose?
23. How many times does Krebs cycle turn with every glucose metabolized?
24. Where in the cell does the second stage of respiration take place?
25. What is the word used to describe the sum of all chemical reactions within an organism?
26. What energy molecule is produced by cellular respiration?
27. What is the starting molecule for glycolysis?
28. What is the substance that is produced during photosynthesis that is used for completion of cellular respiration?
29. What does FAD stand for?
30. Which type of fermentation occurs in yeast?
31. How many ATP are produced by the Krebs cycle to each molecule of glucose?
32. What stage of the cellular respiration occurs in the cytoplasm?
33. What is the end product of glycolysis?
34. What type of ATP synthesis occurs during glycolysis?
35. What does NAD stand for?
36. What does ATP stand for?
37. What is needed for aerobic respiration?
38. What is the jellylike material that makes up much of a cell inside the cell membrane?
39. What is the net production of ATP from one glucose molecule in glycolysis?
40. What is the other name for anaerobic respiration?
41. What is the molecule that acts as a short-term energy carrying molecule for the cell?
42. What cell organelle is specialized in aerobic respiration?
43. The starting materials in a chemical reaction are called _____.
44. Krebs cycle is also called _____.

45. In glycolysis, the activation of glucose is accomplished by _____.
46. The ending materials in a chemical reaction are called _____.
47. The capacity to make things happen or to do work is called _____.

Appendix 7

"VIGOROUS BRAIN EXERCISE" QUESTIONS

1. True or False: Pyruvic acid is oxidized when oxygen is present.
2. True or False: The first stage of cellular respiration occurs in the mitochondria.
3. True or False: Energy is released from foods when the bonds in food molecules are broken during cellular respiration.
4. True or False: Proteins yield the most energy when oxidized in the cellular respiration process.
5. True or False: As protons flow through the ATP synthase, energy is released to combine ADP and inorganic phosphate to form ATP.
6. True or False: Alcoholic fermentation explains why bread dough rises.
7. True or False: Right now, your cells are using mostly anaerobic respiration to make glucose.
8. True or False: Fats contain more energy than glucose.
9. True or False: The high concentration of protons in the inner mitochondrial space represents potential energy.
10. True or False: Cellular respiration creates energy for the plant cell.
11. True or False: Alcohol fermentation produces far more ATP than aerobic respiration.
12. True or False: Carbon dioxide is a necessary ingredient for cellular respiration.
13. True or False: Each step of the cellular respiration process is catalyzed by an enzyme.
14. True or False: Water is a product of cellular respiration.
15. True or False: During the oxidation of glucose, a net gain of ATP only occurs under aerobic conditions.
16. True or False: Plants undergo cellular respiration.
17. True or False: Proteins and fats can be sources of energy provided that they are modified so that they can enter the glucose metabolic pathways.
18. True or False: Some organisms can use both aerobic and anaerobic respiration.
19. True or False: Your body requires energy at all times, even when you are sleeping.
20. True or False: For every acetyl-CoA that enters the Kreb's cycle, the cycle turns twice.
21. True or False: The usefulness of fermentation as a means of deriving energy is limited because the end products are toxic to the producer.
22. Where in the mitochondria does the electron transport chain occur?
23. What type of fermentation occurs in muscle cells after strenuous exercise?
24. What is the final electron acceptor in lactic acid fermentation?
25. Which molecule enters the Kreb's Cycle?
26. What molecules transport electrons during cellular respiration?
27. During aerobic respiration, where is FADH2 produced?
28. Name one commercial product that undergoes alcoholic fermentation.
29. How many ATP molecules are used in the Kreb's cycle?
30. How many ATP molecules are produced in the electron transport chain with each molecule of NADH produced in the cytoplasm?
31. What kind of reaction converts NAD to NADH?
32. What is the beginning process common to both aerobic and anaerobic pathways?
33. During what stage of cellular respiration is the most ATP synthesized?
34. What is the reduced form of FAD?
35. Which stage of aerobic respiration requires CO2?
36. How many ATP molecules are produced in the electron transport chain with each molecule of NADH produced in the mitochondria?
37. During what process of aerobic respiration is NADH produced?
38. For each glucose, how many ATP, CO2, NADH, and FADH2 are produced? (note that NADH and FADH2 are not yet processed in the Electron Transport Chain)

39. How many ATP molecules are produced in the electron transport chain with each molecule of FADH2?
40. What substance is regenerated by fermentation?
41. What stage of cellular respiration oxidizes glucose to two molecules each of pyruvate, ATP, and NADH?
42. What is the oxidized form of NADH?
43. What is the energy-carrying compound that is involved in stage 1 and stage 2 of cellular respiration?
44. What do you call the overall process of utilizing a concentration gradient to produce ATP?
45. What is the beginning molecule for both lactic acid fermentation and alcoholic fermentation?
46. Which stage of aerobic respiration produces ATP and NADH and releases CO2?
47. Name one commercial product that undergoes lactic acid fermentation.
48. In aerobic respiration, which generates more ATP, substrate-level phosphorylation or chemiosmosis?
49. What metabolic process produces either lactic acid or alcohol?
50. When human muscle cells function anaerobically, they produce a waste product that differs from those produced when functioning aerobically. This waste product is called _____.

Appendix 8

"EXTREME BRAIN EXERCISE" QUESTIONS

1. What is the ultimate purpose of cellular respiration?
2. What is the process that happens during electron transport chain?
3. What process breaks down fat and why does the body break down the fat?
4. How is cellular respiration related to photosynthesis?
5. How does fermentation differ from respiration?
6. State the balanced chemical equation of the reaction during alcoholic fermentation?
7. True or False: Many scientists consider respiration to be the most important life process on Earth.
8. What is IUPAC name of pyruvic acid?
9. Combustion reactions and cellular respiration both produce energy. How are they different in terms of the energy they produce?
10. Under low oxygen conditions, the production of lactic acid in your body can lead to_____.
11. What are the proteins of the internal mitochondrial membrane that are specialized in electron transfer called?
12. Explain what happens to the pyruvic acid molecules made by glycolysis when it enters the mitochondria before starting the Krebs cycle.
13. True or False: 39% of the energy in glucose is converted to ATP, the rest is lost as heat.
14. What is the role of the electron transport chain in cellular respiration?
15. Where do carbon atoms in pyruvic acid end up following the Krebs cycle?
16. What ion moves across the membrane from the intermembrane space to the matrix that causes ATP synthase to spin and make ATP?
17. True or false: ATP synthase produces ATP when the H+ flow back into the matrix of the mitochondria.
18. What do you call a situation where there is no available oxygen in the cell stopping cellular respiration and ATP production causing cells to die?
19. Differentiate aerobic respiration from anaerobic respiration in terms of its process.
20. What stage of cellular respiration wherein two 3-carbon sugars are used?
21. True or false: ATP is the "energy currency" of the cell, so it makes sense that a molecule of ATP contains much more chemical energy than a molecule of glucose.
22. True or false: If oxygen is not present in the cell, the pyruvates cannot enter the mitochondria.
23. State the balanced chemical equation of the reaction during lactic acid fermentation.
24. State the balanced chemical equation of the reaction during cellular respiration.
25. What is the reaction in glycolysis that is involved in ATP consumption?
26. Why is aerobic respiration considered more efficient than anaerobic respiration?
27. True or false: Photosynthesis occurs in only some organisms whereas cellular respiration occurs in the cells of all living things.
28. True or false: Aerobic respiration evolved after oxygen was added to the Earth's atmosphere.
29. True or false: The poison cyanide can inhibit the last cytochrome of the electron transport chain, interrupting ATP formation causing the cell to die.
30. True or false: Lactic acid build-up changes the pH level in the muscles.
31. What compound is phosphorylated for ATP formation?
32. What is the purpose of building the concentration gradient of hydrogen ions in the mitochondria?
33. Why is NAD important in fermentation?
34. True or false: The consumption of oxygen has an inverse relationship with metabolic rate of aerobic cells.
35. What is the type of ATP synthesis that occurs during electron transport chain?

36. Under which conditions do cells use fermentation?
37. What role does molecular oxygen play in aerobic respiration?
38. Which among the process of cellular respiration uses NADH and FADH2 to produce ATP?
39. State the difference between aerobic and anaerobic respiration in terms of where it occurs.
40. True or false: Cells with a greater metabolic activity require more energy from ATP molecules than cells with lower metabolic activity.
41. True or false: When energized electrons released by hydrogen donors, NADH and FADH2, pass through a sequence of proteins, they gain energy each time.
42. State one difference between alcoholic fermentation and lactic acid fermentation.
43. What is the difference between aerobic and anaerobic organisms?

Appendix 9

"TEST YOUR LUCK" QUESTIONS

1. What is the intermediate molecule in alcoholic fermentation that is converted into ethanol?
   A. Pyruvic acid C. Glucose
   B. NADH D. ATP
2. Which of the following is the resulting compound when ATP releases energy?
   A. Heat C. ADP
   B. AMP D. Glucose
3. True or False: The first reaction of Krebs cycle produces citric acid.
4. True or False: Glucose is a carbohydrate that stores chemical energy in a concentrated and stable form.
5. True or False: In lactic acid fermentation, pyruvic acid is transformed into lactic acid.
6. Fill in the blank. Water is an end product in _____.
   A. Lactic acid formation C. Electron transport chain
   B. Fermentation D. Krebs cycle
7. How many ATP molecules are produced for each glucose molecule used in fermentation?
   A. 2 C. 6
   B. 4 D. 10
8. What substance causes the acidic flavor of fermented milk?
   A. Malic acid C. Oxaloacetic acid
   B. Lactic acid D. Citric acid
9. True or False: There is a release of CO_2 in alcoholic fermentation.
10. What is the energy-carrying compound that is only produced during the Krebs cycle?
11. True or False: ATP synthase pumps proton by passive transport.
12. Which of the following is considered a waste product of cellular respiration?
    A. ATP C. Glucose
    B. Oxygen D. Carbon dioxide
13. True or False: All life needs energy.
14. True or False: Fermentation causes cakes and breads to grow.
15. True or False: There is a release of CO_2 in lactic acid fermentation.

Appendix 10

TABLE OF SPECIFICATION ("LITTLE BRAIN EXERCISE" QUESTIONS)

Lesson Content	**Cognitive Domains**			
	Remembering	**Understanding**	**Higher Order Thinking Skills (HOTS)**	**Total**
Glycolysis	**Questions #'s** 1**,** 8, 9, 13, 16, 21, 22, 27, 32, 33, 34, 39, and 45			13
Krebs cycle	**Questions #'s** 2, 3, 4, 5, 10, 12, 14, 15, 17, 19, 20, 23, 24, 29, 30, 31, 35, 37, 38, 40, 42 , and 44.			22
Electron Transport Chain	**Question #** 18			1
Cellular Respiration	**Questions #'s,** 6, 7, 11, 25, 26, 28, 36, 41, 43, 46, and 47			11
Overall	**47**	**0**	**0**	**47**

Appendix 11

TABLE OF SPECIFICATION ("VIGOROUS BRAIN EXERCISE" QUESTIONS)

Lesson Content	**Cognitive Domains**			
	Remembering	**Understanding**	**Higher Order Thinking Skills (HOTS)**	**Total**
Glycolysis	**Questions #'s** 1, 6, 11, 15, 24, 27, 28, 32, 37, 40, 41, 45, 47 and 49.			14
Krebs cycle	**Questions #'s** 20, 25, 29, 31, 34, 35, 38, 42, and 46.			9
Electron Transport Chain	**Questions #'s** 5, 9, 22, 30, 33, 36, 39, and 44.			8
Cellular Respiration	**Questions #'s** 2, 3, 4, 7, 8, 10, 12, 13, 14, 16, 17, 18, 19, 21, 23, 26, 43, 48, and 50.			19
Overall	**50**	0	0	**50**

Appendix 12

TABLE OF SPECIFICATION ("EXTREME BRAIN EXERCISE" QUESTIONS)

Lesson Content	**Cognitive Domains**			
	Remembering	**Understanding**	**Higher Order Thinking Skills (HOTS)**	**Total**
Glycolysis	**Questions #'s** 8, 10, 20, 25, 26 and 38.	**Question #** 12		7
Krebs cycle	**Questions #'s** 6, 13, 15, and 23.	**Question #** 33		5
Electron Transport Chain	**Questions #'s** 2, 11, 14, 16, 17, 32, 35, and 41			8
Cellular Respiration	**Questions #'s** 1, 3, 4, 5, 7, 9, 18, 19, 21, 22, 24, 27, 28, 29, 30, 31, 34, 36, 37, 39, 40, 42, and 43.			23
Overall	**41**	**2**	**0**	**43**

Appendix 13

TABLE OF SPECIFICATION ("TEST YOUR LUCK" QUESTIONS)

Lesson Content	**Cognitive Domains**			
	Remembering	**Understanding**	**Higher Order Thinking Skills (HOTS)**	**Total**
Glycolysis	**Questions #'s** 5, 7, 8, 9, 14 and 15.			6
Krebs cycle	**Questions #'s** 3 and 10.			2
Electron Transport Chain	**Question #** 11			1
Cellular Respiration	**Questions #'s** 1, 2, 4, 6, 12 and 13.			6
Overall	**15**	**0**	**0**	**15**

Appendix 14

ACTUAL DESIGN OF THE DEVELOPED BOARD GAME