WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Improving Conceptual Knowledge in Carbon-Nitrogen-Oxygen Cycle through Squid Game Challenge: An Interactive Survival Game Challenge

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A B S T R A C T

The aim of the study was to improve conceptual mastery of the Carbon-Nitrogen-Oxygen (CNO) Cycle among students in Grade 12 Humanities and Social Sciences (HUMSS) at the Masbate National Comprehensive High School (MNCHS) through the Squid Game Challenge - an original, gamified teaching approach in the context of the Squid Game show. The study aimed at answering the following: level of the performance of the students prior to the intervention and after it, the effects of Squid Game Challenge, and its acceptance among the learners. A sample of 30 purposively selected students took part in research under one-group pretest posttest action research design with five sessions based on specific learner model game-based learning design. The collection of data was provided by a teacher-made pre/post-test, an engagement rating scale, a Likert-type motivation survey, and reflection journals of students. The outcomes presented a significant increase in the rate of performance of the experimental group, which increased its average score of 9.77 (48.83%) to 14.87 (74.33%), with the difference resulting in Learning Gain Score (LGS) +5.10. The result of the paired samples t-test showed that there could be a significant difference between pretest and posttest ($t = 7.44$, $p < .05$) and the effect size is large. All dimensions of the Squid Game Challenge were highly acceptable as they were all rated as messages with high acceptability levels (WM = 4.54) showing its capability to increase motivation and engagement. The results confirm that culturally contextualized gamification with reference to insight gained on the principle of experiential learning has the potential to fill conceptual gaps in learners who are not in the Science, Technology, Engineering and Mathematics (STEM) field. The intervention makes a difference in conceptual learning, motivation, and engagement in science by Grade 12 HUMSS students.

Keywords: Gamification, Carbon-Nitrogen-Oxygen Cycle, Squid Game Challenge, Conceptual Knowledge, Non-STEM Education, Student Engagement, Motivation

INTRODUCTION

The problem of teaching complicated and abstracted scientific concepts to students beyond the standard Science Technology Engineering and Mathematics (STEM) pathways continues to be an urgent educational issue of second-level education. In Masbate National Comprehensive High School (MNCHS), most Grade 12 HUMSS (Humanities and Social Sciences) students have always had difficulties in understanding the Carbon-Nitrogen-Oxygen (CNO) Cycle which is one of the core concepts on stellar nucleosynthesis under Physical Science. The origin of this learning issue is not only because astrophysical processes are abstract, but also because they are not taught in a non-contextualized manner that is learner-centered, meant to suit the non-STEM learners.

The researchers noticed this educational gap, which is why they used the Squid Game Challenge, a game-based learning technique focused on survival and powered by pop culture. Its novelty is in the fact that it combines curriculum-driven science content with gamified, interactive experiences based on the principles of experiential learning. Each of the games was designed to reflect a subtopic of the CNO Cycle, and presented in five sessions which would include leaderboards, tokens, and bonus rounds, designed to have students motivated and to stay engaged.

It has been found that gamification could increase student engagement and deep learning, especially when the game content featured culturally relevant topics and allowed learners to have autonomy (Deci & Ryan, 2000; Hamari et al., 2014). Now, through an intervention that employed recognizable entertainment formulas such as Squid Game, the researchers boosted emotional and behavioral engagement, which is also a major academic achievement determinant according to Fredricks et al. (2004). The involvement of interactive experiential learning settings fits well with Experiential Learning Theory postulated by Kolb who believes that students learn better when they are called on to perform, reflect and apply.

In addition, this strategy advances active learning, which aligns with the thrust of Department of Education which is to address ICT, innovation, and learner-centered pedagogies in learning to be applied in the daily classes. Besides enhancing conceptual knowledge and interaction, the intervention is also used as a prototype of how science education can be contextualized in a manner that connects with the varied background and interests of students.

The initial results of the work showed a statistically significant improvement in the conceptual knowledge and active interaction of students, which was confirmed by the indicators of the post-tests, high-level feedback, and the positive notes of students. These results support the idea of cultures-relevant, gamified approaches to demystifying abstract science concepts and the inclusion of learning experiences, particularly in underrepresented academic trajectories.

This research adds to the existing body of knowledge contributing to the practice of using interactive and gamified teaching as a means of educational equality. It is beneficial to goals declared in the Department of Education DepEd Order No. 14, s. 2022 that implies declaring support of scientific research enhancing learning and teaching practices and supporting the growth of inclusive, engaging, and high-quality education accessible to all learners

Statement of the Problem

This study aimed to improve the conceptual understanding of the Carbon-Nitrogen-Oxygen (CNO) Cycle among Grade 12 HUMSS students through the implementation of the Squid Game Challenge—a contextualized, gamified instructional strategy. Specifically, it sought to answer the following research questions: (1) Determine whether there is significant difference between the scores of Grade 12 HUMSS students on the CNO Cycle before and after participating in the Squid Game Challenge activity; (2) Examine the mean level of student engagement and participation during the Squid Game Challenge, as measured using a standardized participation rating scale; (3) Identify the elements of the Squid Game Challenge receive the highest mean scores in terms of student motivation and interest; and (4) Determine how the Squid Game Challenge activity influences students' interest and understanding in CNO cycle.

METHODS

Research Design

The research was designed using mixed methods research design, including both quantitative and qualitative research to evaluate the effectiveness of Squid Game Challenge in helping the learners to understand Carbon-Nitrogen-Oxygen (CNO) Cycle. The quantitative portion followed a quasi-experiment format of a one-group pretest-posttest study, whereas the qualitative aspect was collected as the reflective feedback in the form of the feedback form.

Data Sources

The primary data were sourced from thirty (30) Grade 12 Humanities and Social Sciences (HUMSS) students comprising eleven (11) males and nineteen (19) females from Section Cordiality of Masbate National Comprehensive High School (MNCHS) during the School Year 2025-2026. They were selected by using purposive sampling based on their documented learning difficulties and relatively satisfactory performance in science-related subjects, especially in the CNO Cycle under the subject Physical Science.

Research Procedure

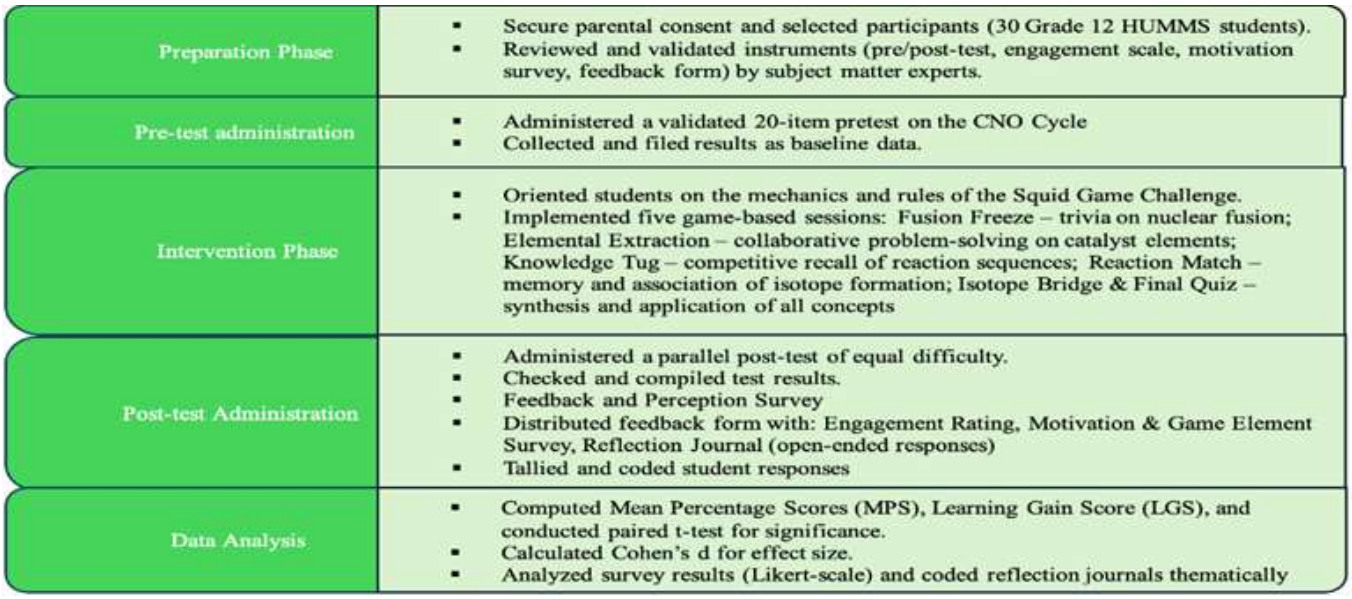

Figure 1. Flowchart of the Research

RESEARCH AND DISCUSSION

Significant difference between Pretest and Post-Test results

The implementation of the Squid Game Challenge as an interactive method of learning intervention helped Grade 12 HUMSS students learn a lot more about the Carbon-Nitrogen-Oxygen (CNO) Cycle. The statistical Analysis of the pretest score together with the post-test score clearly indicates a measure of learning gains that was ascertainable in the course of gamified sessions as revealed by the table below.

Table 1. Measuring the Learning Gain Score (LGS) Based on Pretest and Post-test Results

Measure	**Post-test**	**Pre-test**	**Learning Gain Score (LGS)**
Mean Score	14.87	9.77	5.10
Mean Percentage Score (MPS)	74.33%	48.83%	25.50%
Number of Students	30	30	-

As indicated in the Table 1, the mean score increased from 9.77 to 14.87 resulting to an increase learning gain (LGS) of 5.10 points, while the mean percentage score (MPS) increased from 48.83% to 74.33%, indicating a 25.5% improvement in overall performance. Such a significant increase indicates that the students achieved a better grasp of the science involved in the CNO Cycle. This progress was confirmed statistically by a paired sample t-test.

Table 1. Summary of Paired Sample t-Test Result

Statistic	**Value**
t- stat	7.44
Degrees of Freedom (df)	29
p-value	$1.68 \times 10^{-8} < 0.05$
t-critical	1.70
95% confidence interval	3.70, 6.5

The t-statistics have been calculated as 7.44 with 29 degrees of freedom and this value is greater than the critical value of t which is 1.70 at the 0.05 significance level. The corresponding one-tailed p-value of $1.68x10^{-8}$ is far less than 0.05 This indicates that the difference between the pretest and post-test scores is statistically significant. The 95% confidence interval 3.70 to 6.50 indicates that the true mean difference in scores lies between these values. Since the interval does not include zero, this further confirms that the posttest scores were significantly higher than the pretest scores. Therefore, the null hypothesis is rejected. This justifies that the Squid Game Challenge significantly affected the conceptual understanding of the topic by the students. Hence, the null hypothesis (H_0) which is, there is no significant difference between results of the pretest and posttest is rejected and the alternative hypothesis is accepted which is, there is a significant difference between the result of pretest and posttest of Grade 12 HUMSS students on the CNO Cycle before and after participating in the Squid Game Challenge activity. This result confirmed a statistically significant improvement in learners' performance.

Table 3. Intervention's Practical Significance using Cohen's d

Step	**Computation**	**Value**
1. Mean of Difference Scores ($\bar{d}$)	$\frac{\sum(Posttest - Pretest}{30}$	5.10
2. Standard Deviation of Difference Scores (SDd)	$\sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$	3.75
3. Cohen's d	$\frac{5.10}{3.75}$	1.36

Since the data show presented a statistically significant difference between pretest and posttest using a paired sample t-test, a Cohen's d was conducted to determine the practical significance of Squid Game Challenge as an effective intervention. Based on the Computed Cohen d value of 1.36, the effect size is large according to the criteria of Cohen (1988), where any value that is below 0.2 is small, 0.5 medium, and 0.8 or above is large. This implies that the difference between pre-test and post-test scores in students was not only statistically significant, but also practically significant. Using the Squid Game Challenge as the instructional intervention resulted in a meaningful and significant effect on the conceptual knowledge of the Carbon-Nitrogen-Oxygen (CNO) Cycle among learners. The size of this effect indicates that the gamified approach with cultural contextualization achieved increases in student engagement, motivation, and retention of scientific concepts. The learners could engage with the lesson materials in a competitive, dynamic atmosphere

that culminated in a high level of understanding and quality performance. The high effect size also indicates that the intervention high was extremely successful among the target population and the intervention could be used in further educational learning about science, particularly non-STEM learners who tend to struggle with abstract concepts.

This finding corresponds to Kolb's Experiential Learning Theory (1984), which highlights the fact that knowledge could be more efficiently built when learners are directly involved in the process of experience, reflection and application. In addition to this, gamification, as well as the relevant challenges and feedback, has been found to increase learning motivation and performance (Hamari et al., 2014; Kapp, 2012). The Squid Game Challenge used this more effectively by introducing elements to the game that were familiar with the culture of the players (pop culture-based games). This captured the interest and attention of learners who are not in the STEM program.

Mean level of Student Engagement and Participation

Within the implementation of the Squid Game Challenge, there were five levels of the Squid Game Challenge each corresponded to a subtopic of the CNO Cycle (e.g., Fusion Freeze, Elemental Extraction, Reaction Match). The engagement of the students during intervention took place was measured with the help of a standardized rating scale concerning observable manifestations of interest in the students, including attention, cooperation, and persistence.

Table 4. Mean Engagement Score

Participants (n=30)	**Mean Score**	**Descriptor**	**Interpretation**
Highest Individual Score	5.00	Excellent	Highly Acceptable
Lowest Individual Score	3.40	Good	Acceptable
Overall Engagement Rating	4.50	Excellent	Highly Acceptable

The mean engagement rating was 4.50, this interpret that the instructional intervention is "Highly Acceptable" indicating as highly effective in improving students' academic performance, this means that the students were active, concentrated, and cooperative throughout the Squid Game Challenge. This sustained engagement can be attributed to the competitive yet inclusive game format and the use of visually appealing, structured tasks.

This is consistent with what was said by Moreno and Mayer (2007) who pointed out that active learning environment leads to better retention and improved comprehension than the passive learning process. The immersive experience of the game enabled students to establish personal connection with abstract content to engage more with the process and feel more excited about it. Elements with Highest Means Score of Student Motivation and Interest

Intervention was also scored highly in the learner motivation, where the motivation of students was measured by an already validated Likert-based form of motivation and game design, which evaluated the affective and cognitive elements of their experience.

Mean scores of student motivation and interest

Table 4. Mean Motivational Score

Participants (n=30)	**Mean Score**	**Descriptor**	**Interpretation**
Highest Individual Score	5.00	Excellent	Highly Acceptable
Lowest Individual Score	3.40	Good	Acceptable
Overall Motivational Rating	4.54	Excellent	Highly Acceptable

The mean motivational score of 4.54 is interpret that the instructional intervention is "Highly Acceptable" shows that majority of students strongly felt that the Squid Game Challenge positively influenced the desire to learn in their Physical science lessons about CNO cycle, made the learning process more enjoyable and provided students with a sense of accomplishment. The inclusion of bonus rounds, scoreboards, and team-based challenges were one of the reasons that a casual, yet competitive environment was created, which stimulated intrinsic and extrinsic motivation. The intervention included all the key elements of motivation referred to, as the concepts of student autonomy, competence and relatedness as suggested by Deci and Ryan (2000) in what is known as the Self-Determination Theory. Students were more driven to engage with the subject matter because they felt like there was reward attached to it and which there was some sense of progression in a purposeful manner.

The Squid Game Challenge consisted of five game-based tasks that reinforce the learning of the CNO Cycle using contextualized challenges: Fusion Freeze, Elemental Extraction, Knowledge Tug, Reaction Match and Isotope Bridge. To determine which activities played better compared to others with the students, the students were requested to rate each game based on their preferences in terms of enjoyment, engagement and their perception of learning in support of the games in the following manner: (1) being most favored, (5) being least favored.

Table 5. Ranking of Game Activities Based on Student Preference

Game Element	Mean Score	Rank	Verbal Interpretation
Knowledge Tug	2.8	1	Most Engaging
Elemental Extraction	2.83	2	Highly Engaging
Fusion Freeze	3.07	3	Very Engaging
Isotope Bridge	3.10	4	Moderately Engaging
Reaction Match	3.20	5	Fairly Engaging

It can be observed that the most preferred activity was Knowledge Tug (M = 2.80) followed by Elemental Extraction (M = 2.83). Both of these activities were designed to involve group problem solving and content recall and students thought them to be interesting and challenging. The time factor during tugging answers possibly added a competitive flair to the event in addition to cementing memories- principles of learning through games whereby appropriate challenge gives rise to enhanced learning (Kapp, 2012).

Fusion Freeze (M=3.07) and Isotope Bridge (M=3.20 turned out to have middle ratings, which signifies moderate preference. These games were less complex in regard to mechanics but still managed to integrate with the major concepts of science quite well. Students must have enjoyed the physical and visual qualities of such games, which facilitated experiential learning (Kolb, 1984).

The lowest ranked item was the Reaction Match (M = 3.10) which may have been because of the mental processing involved or the abstract matching task requirement. This correlates with some qualitative data in terms of the reflection journals as students referred to this game as the most challenging or less enjoyable but informative. There is not much difference between the average ranks (2.80 to 3.20), which indicates that none of the five games were disliked and all of them were successful to a good extent.

3.4 Influences students' interest and understanding after implementation

The Squid Game Challenge was shown as an academically effective and engaging intervention to Grade 12 HUMSS students, as demonstrated by the themes that emerge from their responses to the reflection questions:

Table 6. What did you enjoy most about the Squid Game Challenge activity?

Code	Theme	Frequency (n=30)	Sample Response
C	Favorite Game Features	14	"I enjoyed the first activity which is the Fusion Freeze because it was my first activity that makes me nervous and felt so challenged"
B	Collaborative Engagement	4	"I enjoyed the most about the squid game challenge in this activity is the part when we need to do the kapit-bisig because it enhances our skills when it comes to communicating to others and making decisions,"
A	Learning Through Play	3	"I enjoyed learning while playing and laughing, it makes the lesson easier to understand and the way we answered each question with unity and fun,"
F	Entertainment Value	5	I've enjoyed it, as squid game is one of my favorite Netflix series. Also, I had fun learning & playing at the same time due to the fact that it wasn't boring"
E	Incentive-Driven Enjoyment	2	"Receiving rewards when you win the game."
D	Peer Interaction	2	"The cooperation and sportsmanship that I saw while doing the activities"

Game Features was the most common theme, mentioned by 47% of students with many highlighting the competitive and challenging nature of games like "Fusion Freeze" and "Knowledge Tug." Entertainment Value followed, accounting for 17% of responses, with students appreciating how the activity made learning enjoyable. Collaborative Engagement was noted by 13% of students, emphasizing the role of teamwork and communication in their learning process. Learning through Play was mentioned by 10% of students, showing how fun elements facilitated understanding of complex topics. Peer Interaction and Incentive-Driven Enjoyment were cited by 7% of students each, reflecting the value of social engagement and the motivation driven by rewards. Overall, the Squid Game Challenge successfully combined entertainment, collaboration, and rewards to enhance student engagement and understanding of the CNO cycle. This supports the fact that game content promotes attention and engagement (Hamari et al., 2014). The others appreciated the group process and the possibility to cooperate, which shows the social-emotional positive outcomes of the intervention.

Table 7. What part of the activity helped you understand the topic best?

Code	Theme	Frequency (n=30)	Sample Response
A	Gamified Concept Reinforcement	17	"Fusion freeze that helped improved with their trivial questions"
B	Preliminary Content Framing	4	"The part that helped me throughout the activity was the short discussion before the game because it dwells me to learn the CNO Cycle which was almost the coverage of the activity"
C	Collaborative Learning	2	"When we shared knowledge versa, in this way I can acquire more ideas about the topics in fun way."
D	Active Recall Practices	4	"The part of the activity that really helped me to understand the topic is the Reaction Match part because we really need to find first the meaning of the other word so that we can pass the activity."
E	Content Reinforcement	2	"The activity helped me to understand the activity is the Isotope Bridge and final quiz."

Gamified Concept Reinforcement was the most mentioned theme, cited by 57% of students. Students found that combining content with gameplay, like "Fusion Freeze" and "Isotope Bridge," helped them grasp the CNO cycle in an engaging way, with the competitive elements enhancing both engagement and concept reinforcement. Preliminary Content Framing was mentioned by 13% of students, with some students emphasizing the usefulness of brief discussions before the games to set the context and enhance understanding. Active Recall Practices was also highlighted by 13%, with students noting that activities like "Reaction Match" helped them actively recall and reinforce important concepts. Collaborative Learning was cited by 7% of students, who mentioned that working with peers helped them share and develop a deeper understanding of the topic. Content Reinforcement was mentioned by 7% of students, with some stating that activities like "Isotope Bridge" and the final quiz provided opportunities for knowledge reinforcement. Overall, the Squid Game Challenge successfully used a variety of methods, including gamification, collaborative learning, and active recall, to deepen students' understanding of the CNO cycle. This confirms the instructional design since each of the games was directly related to the subtopics in CNO cycle. The integration of remembering, competition, and peer teaching facilitated retention as well as theoretical concreteness (Kolb, 1984; Moreno & Mayer, 2007).

Table 8. Do you have any suggestions to improve the activity in the future?

Code	Theme	Frequency (n=30)	Sample Response
A	Satisfaction with Design	16	"No, I don't have any suggestions cause the activity is really fun and enjoyable."
B	Logistic and Group Management	7	"Minimize the members per group because sometimes there are so many members that others can't contribute or participate."
C	Mechanic Simplification	3	"For me, there are games lack of cooperation- therefore I want to suggest to further improve the game mechanics, to make it more fun for everyone."
D	Inclusivity and Participation	3	Yes, energizer first so that the participants are energized before proceeding with the activities."
E	Facilitator-led Engagement	1	"Actually to me, it is very fun because I observe the teachers giving their fully best to entertain and give knowledge to students."

Satisfaction with Activity Design was the most prominent theme, cited by 53% of students with many appreciating the structure and enjoyment of the activity. Logistic and Group Management was mentioned by 23% of students with suggestions to form smaller groups to encourage more participation. Inclusivity and Participation was highlighted by 10% of students emphasizing the need for energizers to keep all students engaged. Mechanic Simplification was suggested by 10% with students recommending clearer instructions to reduce cognitive load and improve focus. Facilitator-led Engagement was mentioned by only 3% of students indicating that the facilitator's enthusiasm played a role in making the activity more enjoyable. Overall, the Squid Game Challenge successfully engaged students in learning the CNO cycle while providing valuable suggestions for future improvement.

The reflective insights of the students guarantee the fact that Squid Game Challenge has received an immense reception, pedagogy, and teaching. The excitement, learning and motivation was mostly founded in the interactive design, peer relationships, and repetition on the material through games, which is also supported by the evidence-based research and practice on experiential learning (Kolb, 1984) and gamification (Kapp, 2012; Deci & Ryan, 2000).

CONCLUSION

This study concluded that the Squid Game Challenge significantly improves the conceptual knowledge of Grade 12 HUMSS students toward the Carbon-Nitrogen-Oxygen (CNO) Cycle in Physical Science. The study aimed to evaluate the effectiveness of a gamified, pop culture–based intervention as a strategy to enhance science learning at Masbate National Comprehensive High School during the school year 2025–2026. Results indicated that students exposed to the Squid Game Challenge showed marked improvement in their conceptual knowledge compared to their pre-intervention performance. Therefore, the researchers concluded the following:

1. The pretest and posttest results revealed a substantial increase in mean scores, with a learning gain of 5.10 points and a 25.50% improvement in overall performance. The paired samples t-test showed a statistically significant difference ($t = 7.44$, $p < 0.05$), while Cohen's d yielded a value of 1.36, indicating a large effect size. These findings confirm that the intervention produced not only statistically significant but also practically meaningful improvements in conceptual understanding.

2. Engagement and participation levels were rated "High Acceptable" ($M = 4.50/5$), showing that the competitive yet inclusive design sustained students' attention, cooperation, and focus.

3. Motivation scores were likewise "Highly Acceptable" ($M = 4.54/5$), with culturally relevant, gamified elements particularly Knowledge Tug and Elemental Extraction emerging as the most engaging activities. These elements fostered teamwork, problem-solving, and content recall, while even the least-preferred game maintained positive ratings.

4. Reflections from the students further revealed that learning through play, collaboration with peers, and the integration of culturally contextualized game elements deepened their comprehension and enhanced their interest in science. These results confirm that the Squid Game Challenge is an effective, engaging, and motivating pedagogical strategy that makes abstract scientific concepts more meaningful and accessible, especially for non-STEM learners.

Acknowledgements

We, the researchers, would like to thank all the people and institutions that helped us in the implementation of this action research titled, "Improving the Conceptual Knowledge in Carbon-Nitrogen- Oxygen Cycle through Squid Game Challenge: An Interactive Survival Game Challenge." Foremost, we would like to thank Sir Marnel M. Bullo who was always being a good research adviser and gave us constant support, inspiration, and motivation. His suggestions and recommendations were very useful, and our study received a lot of benefits thanks to him. Our gratitude also extends to Ms. Marife A. Cañares, Principal IV of Masbate National Comprehensive High School who had graciously gave us the permission to conduct this research and to Mr. Rogelio C. Caliwan, Senior High School (SHS) Assistant Principal II, who gave us the suggestions and recommendations that had facilitated the realization of this study in the school community. Sir Gerard Jan D. Ibañez deserves special mention as he took time to review and contribute his skills and approval to the pretest, posttest, and research instruments. His steering helped us to make sure that our tools are consistent and dependable with the aims of the study. We would also like to add our gratitude to the Grade 12 HUMSS students of Section Cordiality who showed active involvement and interest in Squid Game Challenge. The fact that they were eager to explore new ways of learning helped in the richness and achievement of this study significantly. To our colleagues and co-teachers, we say thank you, for the help and support, and encouragement. The reason why this effort was even more special is because of your donations, which helped to establish a positive and work-together environment. We wish to thank our families and loved ones for their patience, understanding and emotional support which they have been lavishing on us during the research. They were so constant in their love and helped us through tough situations. We also recognize the international scholarly community and other action researchers whose works we found enriching as inspiration. Their inventions in the field of learning and teaching are what have enhanced the viability of our gamified science learning curriculum. We owe our greatest gratitude to our Almighty God, whose wisdom, strength and grace supported us through the process. This is because this research could not have been conducted without his divine guidance.

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