**Enhancing The Basic Science Process Skills Through Game-Based Learning**

**ABSTRACT**

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| Science process skills are essential for young learners to explore and understand scientific concepts effectively. However, many elementary pupils struggle to acquire these skills due to traditional and passive forms of instruction. Thus, this quasi-experimental research aimed to determine whether Game-Based Learning (GBL) can improve the basic science process skills—specifically observing, classifying, and communicating—of Grade III pupils. The data was gathered through validated pre-test and post-test questionnaires answered by 25 pupils in both the control and experimental groups from Cateel Central Elementary School for the academic year 2024–2025. The intervention lasted for four weeks and focused on reinforcing science process skills through structured game-based activities. Results revealed that both groups started with equal performance, categorized as "Did Not Meet Expectations." After the intervention, the experimental group achieved a "Satisfactory" level, whereas the control group remained in a lower category. Statistical analysis showed a significant difference in the post-test scores between the two groups, with a computed F-value of 4.324 and a p-value of 0.001.  Additionally, the effect size, as measured by Cohen's d, was 1.24, indicating a large effect. Based on the findings, Game-Based Learning is an effective instructional approach in enhancing learners' science process skills. Furthermore, the results of this study are deemed beneficial to students, teachers, school administrators, and future researchers in the field of science education. |

*Keywords: science process skills, game-based learning, quasi-experimental research, pre-test, post-test, control group, experimental group*

**1. INTRODUCTION**

The development of Basic Science Process Skills (BSPS), such as observing, inferring, measuring, classifying, predicting, and communicating, is essential for fostering scientific inquiry and critical thinking in students (Duda & Susilo, 2018). However, many students struggle to master these skills, particularly within traditional educational settings, which often fail to provide interactive and hands-on experiences (Wiseman et al., 2024). As a result, students' ability to engage effectively in scientific investigations is limited, ultimately affecting their overall scientific literacy (Widyaningsih et al., 2020).

Globally, the development of basic science process skills remains a persistent challenge, with a significant number of students failing to acquire essential competencies. The Programme for International Student Assessment (PISA) highlighted that over 40% of students lack proficiency in applying basic science skills in practical contexts, primarily due to ineffective teaching strategies and limited access to inquiry-based learning opportunities (Mostafa, Echazarra, & Guillou, 2018). Similarly, PISA results underscore significant gaps in students' science literacy, particularly in their ability to apply scientific inquiry skills such as explaining phenomena, evaluating inquiries, and interpreting data effectively (Sartika & Kadri, 2019). These gaps are exacerbated in countries where traditional, teacher-centered methods dominate and access to interactive, hands-on science education is limited (Alam, 2023).

In the Philippines, the underdevelopment of basic science process skills among elementary students remains a critical educational concern. Studies have consistently shown that fundamental skills such as observation and classification, which are essential to scientific inquiry, are inadequately developed. Andriani et al. (2025) emphasized this issue, highlighting the lack of foundational science skills among elementary students, while Astuti et al. (2025) revealed that even with modern pedagogical tools, students continue to struggle with basic experimentation processes. Moreover, Yurniwati et al. (2025) noted that without structured interventions, students' critical thinking abilities—a core component of process skills—are significantly hindered, resulting in persistent learning gaps.

Addressing these challenges requires innovative and targeted strategies, one of which is Game-Based Learning (GBL). GBL has gained recognition as an effective educational approach. By fostering interactive and engaging environments, GBL enhances essential skills such as problem-solving and critical thinking (Barr, 2019). Dynamic challenges and immediate feedback provide learners with opportunities to practice and refine their abilities, making it a powerful tool for addressing gaps in science education (Makhija et al., 2022).

Despite the increasing emphasis on innovative pedagogies, there is a notable lack of research specifically addressing the development of basic science process skills. While Game-Based Learning (GBL) has demonstrated potential to improve engagement and academic performance, its effectiveness in fostering these foundational science skills remains insufficiently explored, particularly within the local context. This significant gap underscores the urgent need for studies that focus on enhancing basic science process skills, particularly by utilizing GBL as a means to address critical deficiencies in science education.

**2. OBJECTIVES**

This study primarily aimed to investigate the effectiveness of game-based learning in enhancing fundamental process skills in science education among grade 3 pupils. Specifically, it aimed to:

1. Determine the level of the pre-test scores of the control and experimental groups in terms of basic process skills in science among Grade 3 pupils.
2. Determine the level of the post-test scores of the control and experimental groups in terms of basic process skills in science among Grade 3 pupils.
3. Determine the significant difference in pre-test scores between the control and experimental groups in terms of basic process skills in science.
4. Determine the significant difference in post-test scores between the control and experimental groups in terms of basic process skills in science.
5. Determine the extent to which game-based learning enhances the development of basic science process skills among Grade 3 students.

**3. MATERIALS AND METHODS**

**Research Design**

This study employed a quasi-experimental methodology. According to Appinio (2024), causal research is a methodological approach used in scientific inquiry to investigate cause-and-effect relationships between variables in real-world scenarios. A quasi-experiment is not reliant on the process of random assignment. Instead, participants are allocated to groups based on predefined non-random criteria (Thomas, 2020). The quasi-experimental framework is recognized as suitable for this investigation, as it encompasses pre-existing groups (the control and experimental groups) that are not assigned to random assignment.

**Research Instrument**

This study employed a researcher-designed questionnaire to investigate how game-based learning enhances basic science process skills among Grade 3 students, specifically focusing on two learning competencies: describing changes in weather over time (S3ES-IVe-f-3) and communicating how various types of weather influence community activities (S3ES-IVg-h-4).

The research instrument consisted of a 25-item test questionnaire that underwent rigorous validity and reliability testing. Content validity was established through the evaluation of three experts, who assessed the questionnaire for its alignment with learning outcomes, relevance to objectives, and the quality of individual items. Using Aiken's V coefficient, their ratings yielded a score of 0.96, indicating a high level of validity. To determine reliability, the instrument was pilot-tested in other schools, and Cronbach's alpha coefficient was calculated, resulting in a value of 0.702. This value signified strong reliability and validity for the final research instrument, which ultimately consisted of 29 items.

**Respondents of the Study**

This research focused on Grade 3 students at Cateel Central Elementary School. Two sections were selected for the study: one served as the experimental group, while the other acted as the control group. To ensure fairness and minimize bias, students were assigned to these groups through a coin toss conducted in the presence of the class adviser. The experimental group engaged in game-based learning activities, while the control group received traditional instruction. Data collected from both groups were then compared to assess the effectiveness of the intervention employed.

Throughout the study, ethical considerations were strictly observed. Informed consent was obtained from both the students and their parents or guardians. The confidentiality and privacy of participants' information were rigorously maintained. To ensure the well-being of all participants, only students in good physical condition were included in the study. Those with physical disabilities or conditions that could have hindered their participation in game-based activities were excluded to prevent any potential risks or discomfort during the intervention.

**Data Gathering**

The study implemented a structured data-gathering procedure comprising several key steps:

1. **Ethical Clearance:** The researchers first sought ethical clearance from the University Research Ethics Board (UREB). This step was crucial for ensuring compliance with ethical guidelines and protecting the rights of participants.
2. **Informed Consent:** Parents or guardians received a letter outlining the purpose of the study, which was to assess the understanding of science among Grade 3 students through a pre-test. The letter detailed the activities involved and emphasized that participation was voluntary. Parents were requested to sign and return the assent form granting permission for their child's participation in the study.
3. **Administration of Pre-Test:** Participants underwent a pre-test to assess their prior knowledge related to the competencies targeted in the research. The pre-test consisted of multiple-choice questions designed to establish a baseline understanding of the concepts.
4. **Intervention:** Following the pre-test, the control group continued with traditional instruction according to their regular curriculum. This group received instruction through conventional methods and did not participate in any game-based learning interventions during the study. Meanwhile, the experimental group engaged in game-based learning as an intervention. This approach aimed to involve students and enhance their basic science process skills actively.
5. **Administration of Post-Test:** After the intervention period, a post-test assessment was administered to both groups using a similar multiple-choice test. This assessment evaluated the effectiveness of the intervention by comparing students' basic science process skills before and after the implementation.

**CONTROL**

**GROUP**

**EXPERIMENTAL**

**GROUP**

**PRE-TEST**

**INTEGRATION USING TRADITIONAL TEACHING**

**PRE-TEST**

**INTEGRATION USING GAME-BASED**

**LEARNING**

**POST-TEST**

Figure 1: Data Gathering Procedure

**4. RESULTS AND DISCUSSION**

This chapter presents the results and discussion of the study. The discussion is organized according to the statements of the problem. It includes the corresponding analysis and interpretation of the data.

**Level of Pre-Test Scores**

Table 1 presents a comparison of the pre-test scores between the control and experimental groups. The control group had a mean score of 10.08, while the experimental group scored 10.09; both correspond to a transmuted grade of 70, interpreted as "Did Not Meet Expectations." These results indicate that learners in both groups had not yet achieved the minimum standard in basic science process skills—specifically observing, classifying, and communicating—prior to the intervention. The similarity in scores reflects an equivalent baseline in conceptual understanding.

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| Table 1. Level of pre-test scores between the control and experimental groups | | | | | |
| Group | Total Score | Standard Deviation | Mean | Grade Percentage | Remarks |
| Control | 25 | 3.49 | 10.08 | 70 | Did Not Meet Expectations |
| Experimental | 25 | 3.38 | 10.09 | 70 | Did Not Meet Expectations |

This result is supported by the studies of Villareas (2023) and Mulyeni et al. (2019), which emphasize students’ low mastery of science process skills. This outcome reflects a widespread challenge in elementary science education, where instruction heavily relies on textbook-based methods with limited opportunities for experiential engagement. Similarly, Thankachan (2024) asserted that when instruction is dominated by rote memorization and lacks real-world application, students struggle to transfer knowledge meaningfully, resulting in poor performance and limited long-term retention.

**Level of Post-Test Scores**

Table 2 presents the comparison of post-test scores between the control and experimental groups following the implementation of the Game-Based Learning (GBL) intervention. The control group obtained a mean score of 12.38, corresponding to a grade percentage of 72, which still falls under the "Did Not Meet Expectations" category. In contrast, the experimental group achieved a significantly higher mean score of 17.78 and a grade percentage of 81, classified as "Satisfactory" according to the Department of Education's grading scale. Notably, both groups demonstrated improvement from their pre-test scores, indicating learning gains; however, the progress was more substantial in the experimental group.

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| Table 2. Level of post-test scores between the control and experimental groups | | | | | |
| Group | Total Score | Standard Deviation | Mean | Grade Percentage | Remarks |
| Control | 25 | 5.25 | 12.38 | 72 | Did Not Meet Expectations |
| Experimental | 25 | 3.04 | 17.78 | 81 | Satisfactory |

Further, the improvement was notably greater in the experimental group. While the control group’s post-test performance reflected limited progress, the experimental group advanced to a higher achievement level, corresponding to the 80–84% range. According to DepEd Order No. 8, s. 2015, this level indicates that learners sometimes demonstrate mastery of learning competencies and are generally progressing as expected. This suggests that the intervention applied to the experimental group had a more substantial and compelling impact on enhancing their basic science process skills.

These results are supported by the findings of Yildirim and Şen (2022), who observed that students engaged in game-based science instruction outperformed their peers taught through traditional methods, attributing this advantage to the interactive and hands-on nature of GBL activities. Similarly, Ploensombat and Saeng-ngam (2023) demonstrated that incorporating games into instruction significantly enhanced students' basic science process skills, underscoring the effectiveness of GBL in cultivating essential scientific competencies. Furthermore, Lin and Aloe (2023) reported that game-based learning (GBL) enhances student motivation while fostering critical thinking, problem-solving, and collaboration. By creating immersive and interactive learning environments, GBL provides meaningful contexts for students to practice key science process skills such as observing, classifying, and communicating.

**The Difference in the Pre-test Scores**

Table 3 presents the results of the t-test comparing the pre-test scores of the control and experimental groups. The experimental group recorded a mean score of 10.09 with a standard deviation of 3.38, while the control group had a closely similar mean score of 10.08 and a standard deviation of 3.49. The computed t-value of 0.010 and p-value of 0.992 indicate that there is no statistically significant difference between the pre-test scores of the two groups. This implies that learners across both sections began the study with equivalent levels of understanding regarding the basic science process skills.

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| Table 3. Mean comparison between pre-test scores of control and experimental group | | | | | |
| Group | Mean | Standard Deviation | t-value | p-value | Interpretation |
| Control | 10.08 | 3.49 | 0.010 | 0.992 | There is no significant difference in the average pre-test score between the experimental and control groups. |
| Experimental | 10.09 | 3.38 |

The absence of a significant difference in pre-test scores can be attributed to the similar instructional environments initially experienced by both groups, where passive, textbook-driven teaching methods likely resulted in comparable performance levels. This supports the study of Cajurao et al. (2023), who observed that elementary science instruction in many Philippine schools often lacks experiential learning opportunities necessary for developing process-based skills. Further, Reidy (2021) emphasized that uniform teaching strategies, learning materials, and classroom environments can contribute to homogeneous student outcomes before any intervention is applied.

**The Difference in the Post-Test Scores**

Table 4 presents the results comparing the mean post-test scores of the control and experimental groups. The experimental group obtained a mean score of 17.78 with a standard deviation of 3.04, while the control group achieved a lower mean score of 12.38 with a standard deviation of 5.25. The computed F-value of 4.324 and a p-value of 0.001 indicate a statistically significant difference in the post-test scores between the two groups. This suggests that the intervention applied to the experimental group—Game-Based Learning (GBL), grounded in Johan Huizinga's concept of the Magic Circle—had a meaningful effect on improving learners' performance in basic science process skills.

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| Table 4. Mean comparison between post-test scores of control and experimental group | | | | | |
| Group | Mean | Standard Deviation | F-value | p-value | Interpretation |
| Control | 12.38 | 5.25 | 4.324 | 0.001 | There is a significant difference in the average post-test score between the experimental and control group. |
| Experimental | 17.78 | 3.04 |

These findings are consistent with the study by Whitton and Langan (2019), which reported that students in GBL environments significantly outperformed those in conventional classrooms, particularly in science tasks requiring process-oriented thinking. Likewise, Kuratani et al. (2020) reported that when learners are given opportunities to interact, explore, and apply concepts within gamified environments, their cognitive processing deepens, and retention improves. Furthermore, Yildirim and Şen (2022) emphasized that integrating games into primary science lessons leads to higher achievement and motivation, which is attributed to the interactive and problem-solving nature of the tasks. Similarly, Manzano-León et al. (2021) found that game-based learning environments promote sustained attention, conceptual understanding, and positive attitudes toward learning, especially in skills-based subjects such as science.

**Effects of the Intervention**

Table 5 presents the effect size of the Game-Based Learning (GBL) intervention based on the post-test scores of the experimental and control groups. The computed Cohen’s d value was 1.24, with a 95% confidence interval ranging from 0.62 to 1.85, which, according to Cohen’s (1988) guidelines, indicates a large effect size. This suggests that the GBL intervention had a substantial and statistically meaningful impact on students’ development of basic science process skills.

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| Table 5:Independent samples effect sizes | | | | |
|  | | | **95% Confidence Interval** | |
| **Measures** | **Standardizer** | **Point Estimate** | **Lower** | **Upper** |
| Cohen's d | 4.36 | 1.24 | 0.62 | 1.85 |

The significant improvement observed in the experimental group's post-test scores underscores the effectiveness of the Game-Based Learning (GBL) intervention in enhancing basic science process skills. The enormous effect size indicates that the intervention had a substantial and practical impact on learners' abilities to observe, classify, and communicate scientific information. This result is consistent with the meta-analysis conducted by Alotaibi (2024), which found that game-based learning yields moderate to large effects on skill acquisition in early childhood education. Similarly, a study by Whitton and Langan (2019) emphasized that game-based learning environments facilitate more profound understanding and enhanced skill acquisition. Moreover, Cadiz et al. (2023) found that game-based learning strategies are highly effective in science education, especially in strengthening students' fundamental science process skills.

These findings reinforce the theoretical foundation provided by Johan Huizinga's "Magic Circle" concept, which views structured play as a powerful vehicle for meaningful learning. Within this framework, learners are immersed in a defined space governed by rules and objectives, promoting focused engagement and purposeful exploration of scientific concepts. Such environments enable students to practice essential skills, such as observing, classifying, and communicating. For instance, Uyulan and Aslan (2025) demonstrated that learning environments designed around the Magic Circle significantly enhanced learners' science process skills by fostering engagement, exploration, and hands-on inquiry. Similarly, Whitton et al. (2025) emphasized that the Magic Circle fosters meaningful experiences and intrinsic motivation, which are crucial for developing science process skills. Additionally, Plass et al. (2015) highlighted that the Magic Circle facilitates engagement on multiple levels, including affective, behavioral, cognitive, and sociocultural, thereby creating a holistic learning experience conducive to skill development. These findings affirm that Huizinga's theory remains relevant in modern educational contexts, especially in designing GBL experiences that effectively cultivate core science process skills.

**The Implication of Science Education**

This study aimed to enhance the basic science process skills of Grade III learners through game-based learning, utilizing Johan Huizinga's Game-Based Learning Theory, specifically the "magic circle" framework characterized by challenges, rules, incentives, rewards, and feedback. The results offer valuable insights into how innovative pedagogies can transform traditional science instruction into engaging, inquiry-driven learning experiences.

Science education benefits from instructional approaches that simulate real-world scientific exploration. Game-based learning encourages young students to observe, hypothesize, test, and analyze in a controlled, risk-free environment, all while developing core process skills.

The study suggests the following implications:

1. It helps learners sustain engagement and motivation by using structured challenges and rewards. The game elements draw students into immersive tasks that stimulate curiosity and persistence, making science process skills more enjoyable and meaningful to develop (Adipat et al., 2021).
2. It helps learners develop scientific reasoning through feedback and trial-based decision-making. Games provide immediate feedback that enables students to adjust their strategies, promoting critical thinking and metacognition —essential skills for drawing conclusions and refining experiments (Makhija et al., 2022).
3. It helps teachers implement inquiry-based science instruction by integrating observation, classification, and experimentation into an interactive learning approach. Through gameplay, students naturally practice foundational science process skills, making it easier for teachers to scaffold complex concepts in developmentally appropriate ways (Maulia & Kurniati, 2022).

**5. CONCLUSIONS AND RECOMMENDATIONS**

**Conclusion**

Based on the findings, the following are concluded:

1. The pre-test scores of both the control and experimental groups did not meet expectations, indicating that learners in both groups had limited prior knowledge and varying levels of understanding regarding basic science process skills. This suggested a weak foundational grasp of scientific inquiry at the start of the intervention.
2. The post-test scores revealed a clear distinction in achievement: while the control group still did not meet expectations, the experimental group achieved a reasonably satisfactory level of performance. This demonstrated that game-based learning (GBL) made a significant contribution to the improvement of the experimental group's basic science process skills compared to traditional instruction.
3. The pre-test scores showed no statistically significant difference between the control and experimental groups, indicating that both sets of learners began the study with comparable levels of science process skills. This baseline equivalence suggested that any notable improvements observed in the post-test results could be attributed with confidence to the effects of the instructional intervention.
4. The post-test scores showed a significant difference between the experimental and control groups, indicating that students who received game-based learning instruction demonstrated greater improvement in basic science process skills—specifically in observing, classifying, and communicating—compared to those who underwent conventional teaching methods.
5. The effectiveness of the intervention was statistically supported, as the computed Cohen's d value of 1.24 indicated a large effect size based on the post-test scores. This result underscored that the game-based learning intervention had a substantial and meaningful impact on enhancing students' basic science process skills.

**Recommendation**

Based on the study's results and conclusions, the following recommendations are made:

1. To effectively implement game-based learning in the classroom, teachers may undergo targeted training in designing and facilitating game-based activities. This training may include familiarization with the Magic Circle framework, which can support structured yet engaging learning experiences. Such training may equip educators with the skills needed to integrate game-based strategies that promote critical thinking and active participation.
2. The following sample training plan may be utilized by school management:

**Workshop on Designing Game-Based Activities for Enhancing Science Process Skills Using the Magic Circle Framework**

**Rationale**

The development of science process skills—such as observing, predicting, classifying, and inferring—may be essential in fostering scientific literacy among young learners. Traditional instructional methods may often struggle to cultivate these skills in meaningful and engaging ways. In contrast, Game-Based Learning (GBL) may offer an innovative approach that promotes curiosity, exploration, and deeper understanding through structured play.

This workshop is grounded in Johan Huizinga's Game-Based Learning Theory, specifically the Magic Circle framework, which emphasizes four key components: rules, challenges, incentives and rewards, and feedback and response. These elements may transform routine learning into purposeful engagement, providing opportunities for learners to think critically, solve problems, and reflect on their learning.

To ensure that designed games effectively meet learners' developmental and instructional needs, the workshop should also integrate a session on identifying student needs, helping teachers craft games that are not only educationally sound but also responsive to student readiness and learning profiles.

**Duration**

**1 Day (8 hours)**

**DAY 1 – Workshop Flow**

**1. Introduction (20 minutes)**

* Welcome remarks by facilitators and school administrators.
* Orientation on the training goals and expected outcomes.
* Establishing the relevance of game-based learning to enhancing science process skills.

**2. Icebreaker Activity (10 minutes)**

* A simple group game to simulate the energy and collaboration fostered by game-based instruction.
* Designed to model the dynamics of interactive learning and prepare participants for active participation.

**3. Understanding Game-Based Learning and the Magic Circle (60 minutes)**

* Introduction to the concept of game-based learning.
* Exploration of the Magic Circle elements:
* Rules that define boundaries and structure
* Challenges that encourage critical thinking and problem-solving
* Incentives/Rewards that sustain motivation
* Feedback/Response that drives improvement and reflection
* Discussion on how these elements may support inquiry-based science instruction.

**4. Science Process Skills in Elementary Education (60 minutes)**

* Overview of the five core science process skills: observing, predicting, classifying, inferring, and experimenting.
* Discussion on the cognitive importance and application of these skills in the elementary classroom.
* Examination of how each process skill may be taught through purposeful gameplay.

**5. Lecture-Demonstration and Hands-On Game Design Practice (120 minutes)**

* The facilitator may present sample game-based science activities and demonstrate their alignment with both the Magic Circle and science skills.
* Participants may use a design template to create their classroom-ready games.
* The focus may be on ensuring that game objectives align with learning outcomes and identified student needs.

**6. Group Discussion and Peer Sharing (60 minutes)**

* Participant groups may present their designed games.
* A facilitated peer feedback session may be conducted to refine and improve the game's quality.
* Emphasis may be placed on collaboration and reflective practice.

**7. Lesson Planning and Workshop Evaluation (60 minutes)**

* Participants may create a science lesson plan that integrates their designed game.
* Workshop evaluation may be conducted through structured feedback forms.
* A discussion may take place regarding potential classroom challenges and their solutions.

**8. Conclusion and Closing Ceremony (30 minutes)**

* Recap of key learning insights and highlights of the training.
* Distribution of digital resources (templates, sample games, needs assessment tools).
* Awarding of certificates and facilitator closing remarks.

1. Future researchers may explore the application of game-based activities structured around the Magic Circle model in various science domains, such as environmental science, life systems, and energy transformation, as well as in other subject areas like mathematics, social studies, or language arts. Exploring these areas while considering the specific learning needs of the learners may provide deeper insights into the model's adaptability, ensuring that instructional strategies are responsive, relevant, and impactful across different content areas and learner profiles.
2. Educators and learners can explore online platforms or mobile applications that simulate game-based inquiry, aligning with the Magic Circle framework. These digital tools may enhance flexible, engaging, and meaningful learning experiences in both traditional and blended educational settings.

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