International Journal of Research in Social Science and Humanities (IJRSS)

E-ISSN : 2582-6220

DOI: 10.47505/IJRSS.2025.4.13

Vol. 6 (4) April - 2025

Back2Basics: Developing a Gamified Intervention Material in Teaching Basic Mathematical Skills in Physics

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ABSTRACT

Physics is often seen as a challenging subject. Low achievement in Physics is linked to a need to have strong foundational skills in mathematics aside from comprehension and critical thinking. However, conventional teaching methods often bore students and worsen learning. This study tackled this issue by introducing a Gamified Intervention Class (GIC) designed to improve academic achievement among Grade 8 students. Using a quasi-experimental approach, the study measured student performance through pre- and post- tests in both high and low performing homogeneous sections. The GIC was developed utilizing the "How to Gamify?" model and included elements outlined in Toda (2019) et al's framework. The material underwent reviews and revisions based on ten (10) evaluators to ensure clarity, accuracy, and usability of the material. The findings showed that normalized gain scores improved better in high-performing sections than in low-performing counterparts. In conclusion, the GIC proves to be a potential innovative tool in teaching basic skills in physics due to its fun and enjoyable sensation. However, refinements must be made to help low-performing classes to improve as well.

Key Words: Academic achievement, Basic mathematical skills in physics, Gamification.

1. INTRODUCTION

In the Philippine setting, Physics can be a challenging subject for many students. Often perceived as abstract and formula-heavy, the subject leads to demotivated and lower academic achievement. In one study, Groen et al. (2015) mentioned that a good foundation in mathematics is essential in the fields of Science, Technology, Engineering, and Mathematics. To specify, the failure rate in Physics can be attributed to a lack of understanding of the fundamental basics of a physics problem (Reddy et al., 2017), challenges in terms of critical thinking, comprehension, and literacy (Diate et al., 2021), and poor background in mathematics (Corpuz, 2017).

To combat these difficulties, one suggestion is to provide remediation or enrichment. The Department of Education mandated Memorandum No. 46, series of 2013 which states that new intervention should be done to ensure that poorly performing students would be fully prepared for the next level. Some research in intervention utilizes Strategic Intervention Material (SIM). In the context of the Philippine curriculum. Some notable papers by Manlapig et al. (2024), De Jesus (2019), and Espinosa et al. (2014) used SIM in the fields of Physics, Biology, and Chemistry, respectively. These papers also showed that post-test scores improve upon implementation of SIM. Conversely, some issues arise in the use of SIM as Payot et al. (2022) explored these challenges. The authors pointed out that there was a lack of student responses since students could not comprehend the material, and students lacked attention on completing the SIM material as they focused on enjoying the colors and pictures. With these issues, a new way of remediating physics skills must be suggested – Gamification.

As a consensus, gamification is defined as the use of game elements, mechanics, features, design, and structure in a non-game environment or context (Seaborn & Fels, 2015). According to Almeida et al. (2019), gamification has been utilized in many fields such as business, language learning, social networks, healthcare, and education. In education,

gamification provides students with an environment in which a game-like structure is given to students. Researchers notably emphasize the effects of gamification in education to the improvement of not just achievement (Tolentino et al., 2019) but even motivation (dela Cruz et al., 2018), and engagement (Amado et al., 2019) in multiple science disciplines.

In summary, this study aims to address this gap by investigating the feasibility and impact of configuring a gamified learning environment for an intervention class in physics. By examining student achievement, motivation, this research seeks to contribute valuable insights into the potential of gamification as a pedagogical tool in Philippine science classrooms.

The main objective of this study is to develop and evaluate a gamified intervention class (GIC) in physics and determine the effect of GIC to student achievement.

2. METHOD

2.1 Research Design

This study utilized a quasi-experimental design with quantitative and qualitative support. Quantitative data was attained in the form of the surveys administered before and after the implementation of the gamified intervention class. Values from the pretest and posttest of the achievement were taken as data. On the other hand, the qualitative data was collected from the feedback and insights from the respondents.

2.2 Research Subjects and Participants

The respondents of the study will be all the students in the Grade 8 level for the school year 2024-2025 of a private institution. The grade 8 level has two homogenous high-performing sections, and two homogenous low-performing sections. The said category of students was chosen because topics chosen for the intervention were already taught in previous levels and it is appropriate for the 8th grade level to review back on chosen topics. Furthermore, the researcher would also be the implementer of the developed gamified intervention program. The following table shows the distribution of the population for each section.

2.3 Data Gathering Procedure

The study will utilize the “How to Gamify?” model by Morschheuser et al. (2017). Each step is termed a phase. The following figure shows the whole phases in this framework.

2.3.1 Project Preparation, Analysis, and Ideation Phases

The first three phases will feature a researcher-focused aspect. In the Project Preparation Phase, the researcher identifies the objective and assesses if gamification is needed in the objective recognized. Next, the Analysis Phase focuses on determining the context of gamification and identifying the target group. In the third phase, Ideation, before the actual design of the gamification is made, there is a need for a rough path of the gamification design. The Design of Prototypes Phase focuses on identifying how each of the game elements should be present in the GIC. The elements to be used will be based on the twenty-one (21) identified gamification elements recognized by Toda et al. (2019). After the design, the prototype is crafted. The prototype will consist of the GIC Student Module.

DOI: 10.47505/IJRSS.2025.4.13

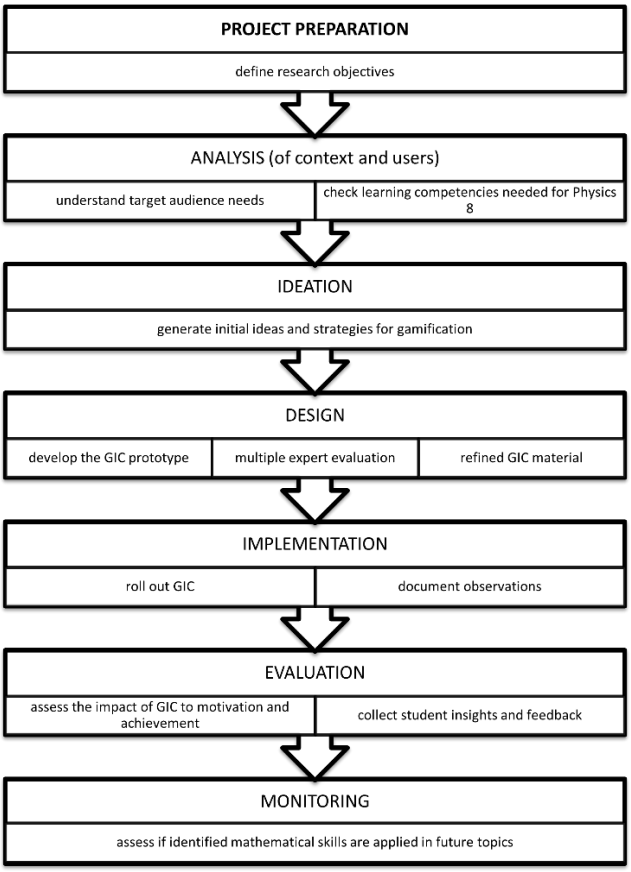

Figure 1: "How to Gamify" Model by Morschheuser et al. (2017)

2.3.2 Implementation Phase

The material shall be initially evaluated before implementation. Initially, an expert panel of five (5) members will do the evaluation. The evaluation will consist of construct, content, and face validity. Comments and suggestions by the panel will be analyzed through thematic analysis (Braun et al., 2006). The second prototype will be the next product after acknowledging the suggestions set by the adviser. Once done, the module shall be evaluated by another five (5) practitioners who are physics teachers at the researched school. The evaluation tool that will be used is the Department of Education (DepEd)'s Evaluation Rating Sheet for PRINT Resources. Once the evaluation is done, the final version is made based on the recommendations. Furthermore, the researcher-made achievement test was also tested for reliability. It was pilot studied to another set of students. Based on the pilot test, of the original 25 items, only one (1) was removed. The basis of removal, retainment, and revision is based on Magno et al. (2010) interpretation guideline and Dela Peña et al. (2011) cross-tabulation table.

Then, actual implementation was done. The whole study covers seven 50-minute sessions. Respondents will take the researcher-made achievement test before implementation. The unit will feature five (5) units and so, 5 quests. Each unit has an input portion from which the lesson objectives, an introduction activity, lesson input proper, and examples shall be provided. Then, instead of doing worksheets, students play quests. Leaderboards are to be updated on a session basis. This shall be posted in the classroom and the group chat of the class. On the last day, the post test was conducted. The test consists of the researcher-made achievement test given on the first day. Furthermore, the respondents also took the researcher-made questionnaire for gamification experience. This is evident in the last stage of the framework, the Evaluation Phase.

2.3.3 Evaluation Phase

Performance was measured using the researcher-made achievement test. The final test will now be given, and scores will reveal how the students know the topic well. The pretest and post test results shall be evaluated based on the

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normalized gain of the group. According to Coletta et al. (2020) normalized gain is favored since it is free of bias toward general groups. When comparing groups, the commonly used t-test has been shown to bias the general group. Since, the study covers groups which are considered as high and low-performing it is very appropriate to use the normalized gain. Hake's (1998) criteria were used to measure normalized gain

3. RESULTS AND DISCUSSION

3.1 Development and Evaluation of the Material

The initial prototype introduced terms found in a popular game played by research participants. However, one major comment of the panel on the initial evaluation was about copywrite issues. To avoid any copywrite infringement, a new prototype was made.

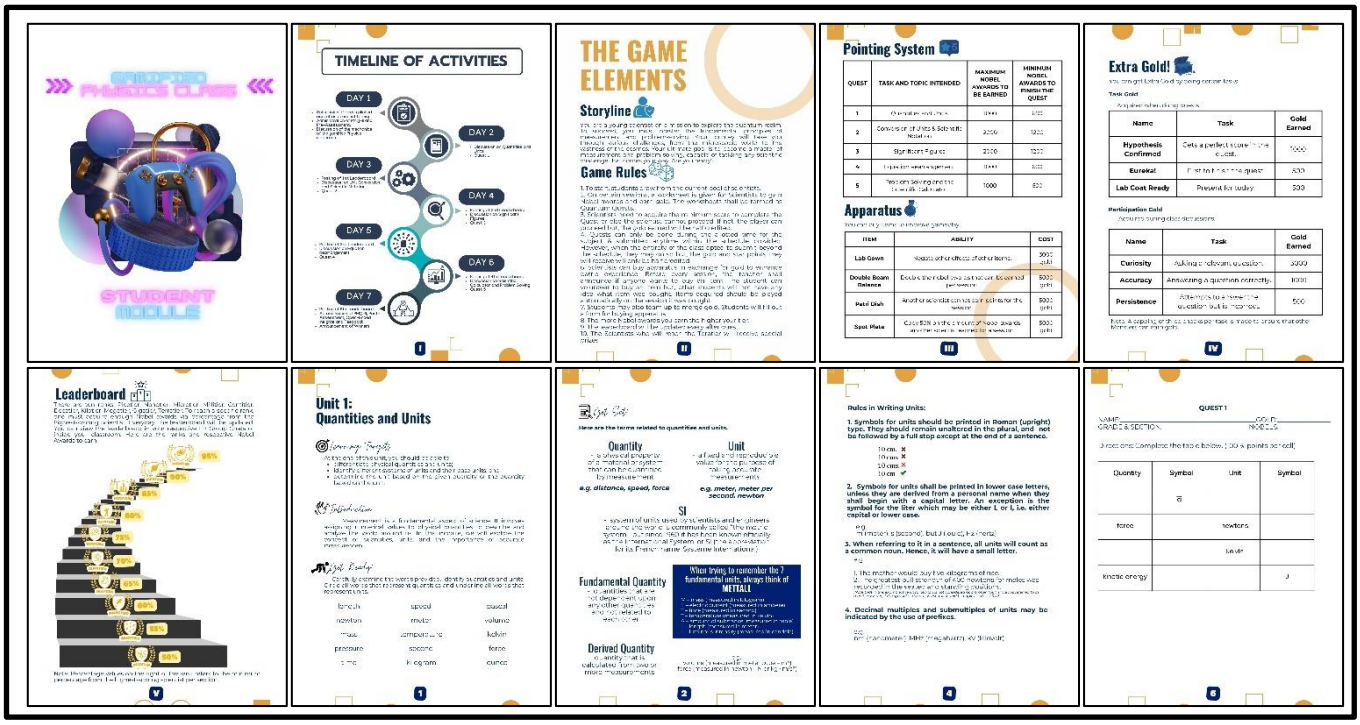

Figure 2: Prototype 2

This version was then critiqued by another 5 people, this time the physics education practitioners of the targeted school. The following table show the results after the practitioners rated it using the DepEd Evaluation Sheet for PRINT resources.

Table 1. Summary of Results for Evaluation Sheet

Factor	E1	E2	E3	E4	E5	Mean
Content	26	23	28	28	26	26.6
Format	68	65	69	71	66	67.8
Presentation and Organization	20	19	20	20	18	19.4
Accuracy and Up-to-datedness of Information	22	23	22	23	22	22.4

Note: E1 – Practitioner 1, E2 – Practitioner 2, E3 – Practitioner 3, E4 – Practitioner 4, E5 – Practitioner 5

All the five factors in the DepEd evaluation sheet for PRINT materials passed except for the one - Accuracy and Up-to-Datedness. Elements under this factor must be addressed. Furthermore, the evaluators also gave comments which is summarized in the table below.

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Table 2. Summary of Notable Comments

Factor or Themes	Subtheme	Comments
Content	Instructions	"…clearer instruction for some game mechanics (such as gold usage and apparatus benefits) could help students navigate the system more effectively." – E5
	Examples	"…more examples or visual aids to clarify complex concepts…" - E5
Format	Readability	"The font size on the table of prefixes on page 5 may be too small…" - E1
		"…increase the font size it's too small for me…" - E3
	Binding and Reproduction	"The illustration on the cover page is not very clear …" – E1
	Markers	"Some units don't have "get set" marker (Unit 3, 4, 5)" - E3
Presentation and Organization	Clarity and Layout	"p.23 the page number covers one cell of the table." – E4
Accuracy and Up-to-datedness of Information	Conventions	"the subscript (2) in the acceleration unit is missing" – E3

Based on these evaluations, the final version was made. The following figure shows the final version.

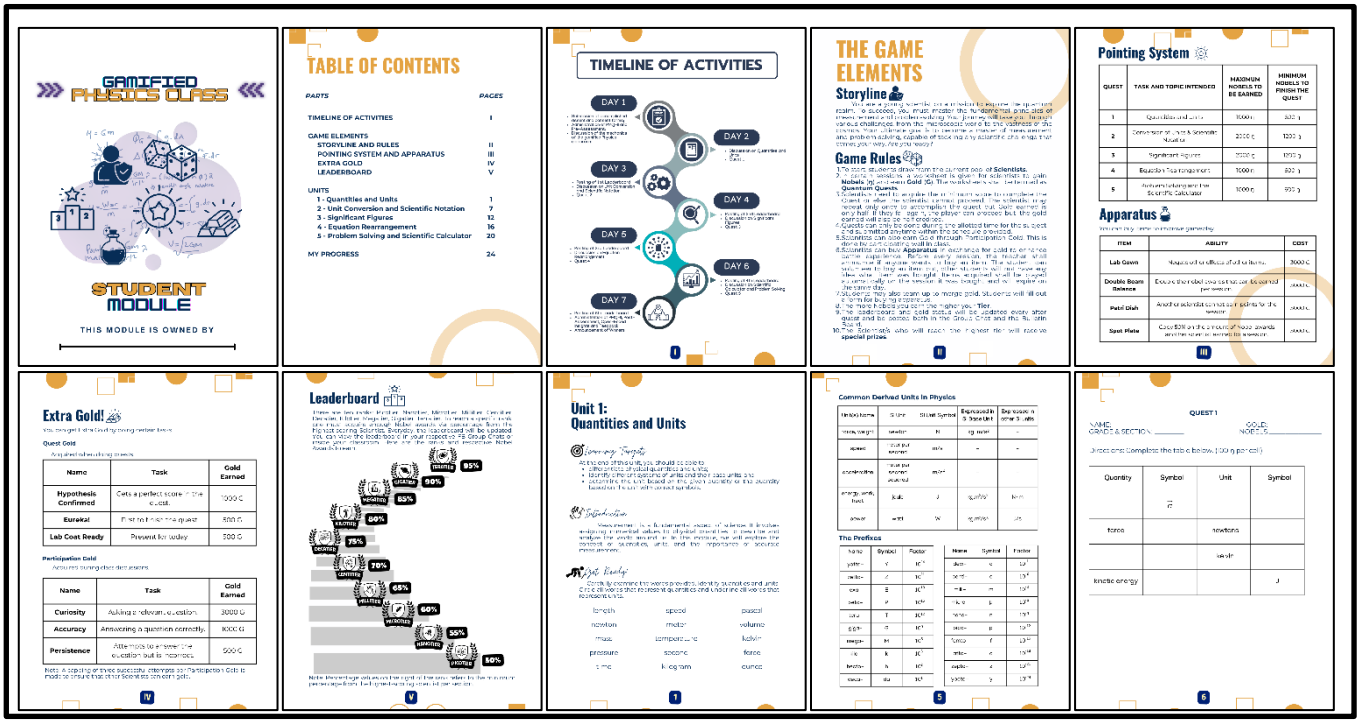

Figure 2: Final Version

3.2 Student Achievement

Student achievement is defined refers to scores of students in the pretest and posttest. A researcher-made questionnaire was made to evaluate student achievement. Normalized gain was used to see if posttest scores have improved after the implementation of the GIC compared to pretest scores. The following table shows the average pretest and posttest scores, and the normalized gain with its corresponding interpretations of the four participating sections.

Table 3. Normalized Gain Scores

DOI: 10.47505/IJRSS.2025.4.13

Section	Pretest	Posttest	Normalized Gain	Interpretation
A	11.12	14.68	0.28	Low
B	9.93	12.41	0.18	Low
C	8.52	9.92	0.09	Low
D	7.08	8.29	0.07	Low
H	10.52	13.54	0.22	Low
G	7.80	9.11	0.08	Low
Overall	9.16	11.32	0.15	Low

Note. H – homogeneous high-performing sections (A & B), G – homogeneous low-performing sections (C & D)

As observed in Table 2, normalized gain interpretations for all sections are low. For Sections A and B, each had normalized gains of 0.28 and 0.18, respectively. Comparing this, only Section A reached a normalized gain that is near to the average of 0.27 in Tolentino et. al (2017) results. To add, Section C had 0.09 while Section D had 0.07 has its normalized gain change. These values, though interpreted as low is near to the stable verbal analysis. With this, the GIC is only effective on homogenous high-performing sections compared to the low-performing counterparts. However, the study has the same result with Sanchez et al. (2020) where only high-achieving students benefited from the gamification context.

It should be noted that there are other factors that cannot be controlled by the researcher. For one, study habits can affect one's performance. As mentioned by Helali et al. (2022), study habits have positive effects to academic standings. Typically, low-performing students have poor study habits as well. In the studies of Renes et al. (2020) and Jiang et al. (2023), Spanish and Chinese high-achieving students used study habits well successfully while low-achieving students do not. In the Philippine setting, the same pattern is found in the studies of Barcenas et al. (2022), Tagud et al. (2023), and Ramos (2024). Observations by the researcher revealed that these sections also made absences more than high-achieving sections and even had longer time in answering the Quests.

4. CONCLUSION AND RECOMMENDATION

To conclude, the Gamified Intervention Class (GIC) demonstrated its potential to be an innovative tool in the hope of improving student achievement. By integrating game elements based on founded frameworks and refining its prototypes through expert evaluation, the GIC has potential to increase academic performance for high-performing sections. However, as no program is perfect, the GIC failed to improve scores for the low-performing sections. There are still several factors to consider for future research on the implementation of GIC. For one, there is a need to find more reasons why only the high-performing sections improved. To add, aside from tweaking some features of the game, there are still less studies in low-resource settings such as far-flung public schools. In addition, the GIC can be also converted into the digital type for schools which have resources to do such. The common use of gamifying other topics can also be utilized. Finally, the psychological aspects of students can also be studied to see deeply the effects of gamification.

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