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TitraGO: A Structured Gamification Approach to Enhance Conceptual Mastery in Acid–Base Titration

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ABSTRACT

Acid–base titration is a core topic in foundation and matriculation chemistry, yet many students struggle to connect conceptual understanding with quantitative problem-solving. Traditional drill-based approaches often fail to effectively address students' misconceptions. This study introduces TitraGO, a structured gamification tool designed to reinforce key titration concepts through an interactive 5×5 BINGO-based format. The activity targets essential skills, including pH and pOH calculations, determination of $[H_3O^+]$and $[OH^-]$, titration curve analysis, and indicator selection. TitraGO utilises a set of reusable cards containing 25 answer squares arranged randomly, paired with a corresponding problem deck. Students solve structured problems and match their answers on the grid, promoting active recall and immediate formative assessment. A pilot study involving 33 pre-university students is conducted to evaluate its effectiveness through perception surveys and classroom observations. The findings indicate a strong positive response, with approximately 99% of students reporting increased engagement and improved understanding of titration concepts. Observations reveal that the competitive and time-sensitive nature of the activity encourages rapid problem-solving, sustained focus, and repeated practice within a short period. The randomized card structure introduces an element of chance, fostering a more inclusive environment where students of varying ability levels remain motivated to participate. In conclusion, TitraGO provides a scalable, low-cost, and pedagogically sound approach that enhances conceptual understanding and problem-solving proficiency, while supporting inclusive and student-centered learning in chemistry education.

Keywords: gamification, acid-base titration, chemistry education, formative assessment, active learning

1. INTRODUCTION

Acid–base titration is a fundamental topic in pre-university chemistry, yet many students struggle to develop a coherent understanding of its underlying concepts. Common difficulties include interpreting pH changes, selecting appropriate indicators, and linking theoretical concept to experimental data (Salame et al., 2022). Traditional teaching approaches often emphasize procedural calculations, which may limit opportunities for deeper conceptual engagement.

To address this gap, this study introduces TitraGO, a structured gamification framework designed to combine problem-solving, formative assessment, and student interaction within a single learning activity. Gamification has been widely reported to enhance student motivation, engagement, and learning outcomes in chemistry education (Chans & Castro, 2021; Smiderle

et al., 2020). The objectives of this study are to enhance students' conceptual mastery of titration and to evaluate their perceptions of gamified learning as an instructional strategy.

2. METHODOLOGY

A pilot study was conducted with 33 pre-university students in a controlled classroom setting. TitraGO adopts a 5×5 BINGO-inspired format, where students solve a series of titration-related problems mapped to values on randomized grids. The tasks range from basic molarity calculations to more complex analyses, including analysis of buffer regions and titration curve interpretation, aligning with active learning strategies used in game-based chemistry instruction (Lathwesen & Belova, 2024).

Students mark their grids upon obtaining correct answers, and the activity concludes when a participant completes two lines and calls out "TitraGO." Answer values are presented on reusable cards with randomized arrangements, allowing efficient use across multiple classes.

The game structure provides immediate feedback, as incorrect solutions hinder progression within the grid. Data were collected through post-activity perception surveys and classroom observations, focusing on engagement, critical thinking, and learning behaviours.

3. RESULTS AND DISCUSSION

The findings indicate a strong positive response to the TitraGO framework, based on the post-activity survey conducted among participants. Students generally reported that the game enhanced their understanding of acid–base titration concepts and provided meaningful practice in solving calculation-based problems. In addition, the majority perceived the activity as engaging, enjoyable, and effective in promoting active participation.

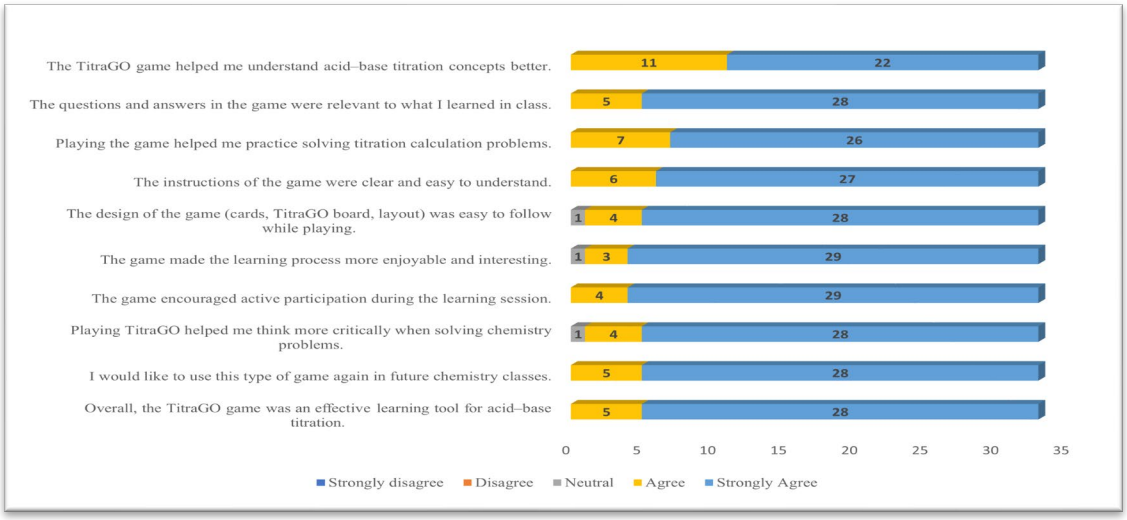


Figure 1. Student Responses to the Post-activity Survey on TitraGO Effectiveness (n = 33).

As shown in Figure 1, responses were strongly skewed towards "agree" and "strongly agree" across all items, particularly in areas related to conceptual understanding, engagement, and overall effectiveness of the activity. Classroom observations supported these findings, where students remained highly focused and demonstrated a strong sense of urgency in solving problems. Most participants worked independently and attempted to progress quickly within the game, relying on rapid reasoning rather than prolonged discussion.

The competitive nature of the activity encouraged continuous problem-solving and reduced hesitation, allowing students to engage in repeated practice within a short period. Students who initially struggled with calculations were observed to participate more actively under this setting, demonstrating increased effort and persistence. Furthermore, the randomized structure of the TitraGO cards introduced an element of chance, ensuring that outcomes were not solely dependent on speed or prior knowledge. This contributed to a more inclusive environment, where a wider range of students remained motivated to participate and improve.

Notably, no responses were recorded in the "strongly disagree" category, indicating consistently positive perceptions of the activity. These findings suggest that the integration of structured gamification through TitraGO not only enhances engagement but also supports rapid practice and more equitable participation, ultimately reinforcing conceptual understanding in chemistry.

4. CONCLUSION

TitraGO demonstrates that effective instructional innovation does not require extensive resources or complex implementation. The framework is low-cost, reusable, and adaptable to other conceptually challenging topics within STEM education. By embedding formative assessment within gameplay, it provides a practical approach to enhancing both engagement and conceptual understanding.

While the results are promising, the study is limited by its small sample size and reliance on self-reported data. Future research could incorporate controlled comparisons and performance-based assessments to further validate its effectiveness.

Overall, TitraGO offers a scalable and accessible model for improving chemistry education, aligning with the broader goals of promoting inclusive and high-quality learning experiences.

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