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# LabQuest: Examining the Effectiveness of a Board Game-Based Learning Approach in Laboratory Quality Management Education

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### ABSTRACT

Game-based learning has gained increasing attention as an alternative pedagogical approach to address limitations of conventional, lecture-centred instruction, particularly in subjects that involve abstract and procedural concepts. Grounded in constructivist and experiential learning perspectives, this study examines the effectiveness of LabQuest, a board game-based learning intervention designed to support students' understanding of laboratory quality management concepts. A mixed-method approach was employed, involving pre- and post-test assessments and student perception surveys, to evaluate changes in learning outcomes, engagement and understanding. The findings indicate that students who participated in the board game-assisted learning activities demonstrated improved comprehension of quality management principles and higher levels of learning engagement compared to conventional instructional approaches. Qualitative feedback further suggests that the interactive and experiential nature of the board game facilitated discussion, collaborative problem solving and application of theoretical concepts in simulated scenarios. Although the study focused on technical undergraduate students, the results suggest that board game-based learning has broader potential as an effective instructional strategy across different educational contexts. This study contributes empirical evidence to the growing body of research on game-based learning by demonstrating its applicability in supporting complex learning processes within quality management education.

## 1. Introduction

Contemporary higher education faces increasing challenges in sustaining student engagement and meaningful learning, particularly in subjects that rely heavily on procedural knowledge and abstract frameworks. Traditional lecture-based instruction often positions learners as passive recipients of information, which may limit motivation, interaction and long-term retention of

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knowledge. As a result, educators have increasingly explored alternative pedagogical strategies that promote active participation, experiential learning and learner-centered environments. Among these approaches, game-based learning has gained attention for its potential to enhance engagement, motivation and collaborative learning through structured yet interactive experiences [1-3]. Board games, as a form of game-based learning, provide learners with opportunities to engage in problem solving, decision making and peer interaction within simulated contexts [4,5]. Previous studies have shown that board game-based learning can foster critical thinking, teamwork and discussion, while supporting experiential understanding of complex subject matter [6,7]. The interactive nature of board games encourages learners to actively construct knowledge rather than passively consume content, thereby aligning with contemporary educational theories that emphasize learning as a social and participatory process [8,9].

Laboratory quality management represents a learning domain that is particularly challenging for students due to its abstract concepts, standardized procedures and emphasis on compliance-oriented decision making [10]. While quality management frameworks are essential for ensuring reliability and accountability in professional practice, students often struggle to contextualize these principles when taught solely through lectures and theoretical explanations. This disconnects between theoretical instruction and practical understanding highlights the need for instructional approaches that allow learners to experience quality management concepts in applied and meaningful ways. Game-based learning offers a promising means to address these challenges by embedding learning objectives within simulated scenarios that mirror real-world decision-making processes. Through gameplay, learners can experiment with choices, experience consequences and engage in reflective discussion, thereby supporting deeper conceptual understanding and behavioral engagement [11].

Despite the growing interest in game-based learning, empirical evidence examining the effectiveness of board game-based learning interventions in laboratory quality management education remains limited, particularly within higher education contexts that involve abstract, procedural and compliance-oriented content. Existing studies have largely focused on learner enjoyment or general engagement, with comparatively less emphasis on measured learning outcomes and student learning behavior. Addressing this gap is significant, as laboratory quality management represents a challenging learning domain where conventional lecture-based approaches may not adequately support experiential understanding or application of concepts. Therefore, this study aims to examine the effectiveness of a board game-based learning intervention (LabQuest) in supporting students' understanding, engagement and learning behavior in laboratory quality management education. Specifically, the objectives of this study are to: (i) compare learning outcomes between students exposed to board game-assisted learning and those receiving conventional instruction; (ii) evaluate students' perceptions of engagement, clarity and learning experience during the intervention; and (iii) explore qualitative feedback to gain deeper insights into students' learning experiences.

## **2. Methodology**

### *2.1 Research Design*

This study adopted a mixed-method research design to examine the effectiveness of a board game-based learning intervention in supporting students' understanding and engagement in laboratory quality management education. Quantitative data were collected using pre- and post-test assessments to measure changes in learning outcomes, while qualitative data were gathered through questionnaires, open-ended responses and classroom observation to capture students' perceptions,

engagement and learning experiences. The mixed-method approach enabled a comprehensive evaluation of both measurable learning gains and behavioral responses to the intervention.

## 2.2 Participants and Learning Context

The participants consisted of undergraduate students enrolled in the Laboratory Quality Management & Validation course offered by the university. Two groups were involved in the study: a test group, which participated in board game-assisted learning activities and a control group, which received conventional lecture-based instruction. The test group comprised 13 students from the Bachelor of Applied Science in Industrial Chemistry with Honours program, while the control group comprised 28 students from the Bachelor of Applied Science in Industrial Biotechnology with Honours program. The unequal group sizes reflect actual course enrolment during the semester and could not be controlled, as the study was conducted within a naturally occurring classroom setting. All participants had comparable exposure to laboratory-related coursework and were at a similar academic level.

## 2.3 Learning Intervention

The learning intervention involved the use of LabQuest, a board game designed to facilitate experiential learning of laboratory quality management concepts. Rather than serving as a replacement for conventional instruction, the board game was implemented as a supplementary learning activity to reinforce theoretical content delivered during lectures. The game sessions were structured to encourage interaction, discussion and collaborative decision making among students, enabling them to apply abstract quality management principles within simulated scenarios. The instructor acted as a facilitator during gameplay, providing minimal guidance to allow learners to independently explore concepts and reflect on their decisions.

## 2.4 Data Collection Instruments

Multiple instruments were used to capture learning outcomes and behavioral responses as depicted in Table 1.

**Table 1**  
Data collection instruments used in the study

| Instrument                  | Purpose  | Data Type    |
|-----------------------------|--|--------------|
| Pre-test questionnaire      | Likert scale items and multiple-choice questions administered before the instructional intervention to assess students' initial understanding, familiarity and comprehension of laboratory quality management concepts | Quantitative |
| Post-test questionnaire     | Likert scale items and multiple-choice questions administered after the instructional intervention to evaluate changes in learning outcomes and conceptual understanding   | Quantitative |
| Student perception survey   | Structured Likert scale questionnaire assessing clarity, engagement, applicability, usability and social interaction during the board game-based learning activities   | Quantitative |
| Open-ended survey questions | Open-ended questions used to gather detailed feedback on students' perceptions, preferences and suggestions related to the board game intervention   | Qualitative  |

Classroom observation

Instructor observations during gameplay sessions focusing on student interaction, participation, collaboration and engagement

Qualitative

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## 2.5 Procedure and Data Analysis

The study was conducted over the first half of the academic semester. Both groups completed a baseline pre-test prior to formal instruction. The test group subsequently participated in multiple supervised board game sessions, each lasting approximately two hours, conducted in a classroom setting. The control group received conventional lecture-based instruction without the use of the board game. Upon completion of the instructional period, both groups completed post-test assessments. Qualitative feedback was collected immediately following the gameplay sessions to capture students' reflections while the learning experience was still recent.

Quantitative data were analyzed using descriptive statistical methods to compare pre- and post-test results between the test and control groups. Frequency, percentages and mean scores were used to identify trends in learning outcomes. Qualitative data from open-ended responses were analyzed using thematic analysis to identify recurring patterns related to engagement, learning experience and perceived effectiveness of the board game-based learning intervention. The integration of quantitative and qualitative findings allowed for triangulation and strengthened the validity of the results.

## 3. Results and Discussion

### 3.1 Baseline Learning Characteristics of Participants

Prior to the instructional intervention, a baseline pre-test was administered to both the control group (BSB) and the test group (BSK) to assess students' self-reported familiarity, knowledge and comprehension of laboratory quality management concepts. The results indicate that both groups possessed a basic foundational understanding of quality management principles before formal instruction. As shown in Table 2, most students in the control group rated their prior understanding as "Good" (67.4%), while students in the test group most frequently selected "Acceptable" (50.5%) and "Good" (41.8%). Only a small proportion of students in both groups rated their understanding as "Poor", suggesting that participants entered the course with some awareness of quality management concepts. These findings indicate that both groups were reasonably comparable at baseline, providing an appropriate foundation for examining the effects of the board game-based learning intervention.

### 3.2 Changes in Learning Outcomes Following the Intervention

Following completion of the instructional period, post-test evaluations revealed notable differences between the test group and the control group. As illustrated in Table 2, the proportion of students in the test group rating their understanding as "Excellent" increased substantially from 1.1% in the pre-test to 54.9% in the post-test. Concurrently, "Acceptable" ratings declined sharply, indicating a shift toward higher perceived mastery of laboratory quality management concepts. Although improvements were also observed in the control group, the magnitude of change was less pronounced. While the proportion of "Excellent" ratings increased from 14.8% to 47.4%, the overall distribution suggests more modest gains compared to the test group. These results suggest that the inclusion of board game-assisted learning contributed to enhanced learning outcomes beyond those achieved through conventional lecture-based instruction alone. The observed improvement aligns

with prior findings that experiential and game-based learning environments support deeper conceptual understanding by requiring learners to actively apply knowledge rather than passively receive information [12].

**Table 2**

Pre- and post-course evaluation on Likert scale questions for BSB and BSK groups

| Scale          | BSB (Control) |       |      |       | BSK (Include board game) |       |      |       |
|----------------|---------------|-------|------|-------|--------------------------|-------|------|-------|
|                | Pre           |       | Post |       | Pre                      |       | Post |       |
|                | f             | %     | f    | %     | f                        | %     | f    | %     |
| 1 (Poor)       | 1             | 0.5   | 0    | 0.0   | 6                        | 6.6   | 0    | 0.0   |
| 2 (Acceptable) | 34            | 17.3  | 6    | 3.1   | 46                       | 50.5  | 2    | 2.2   |
| 3 (Good)       | 132           | 67.4  | 97   | 49.5  | 38                       | 41.8  | 39   | 42.9  |
| 4 (Excellent)  | 29            | 14.8  | 93   | 47.4  | 1                        | 1.1   | 50   | 54.9  |
| Total          | 196           | 100.0 | 196  | 100.0 | 91                       | 100.0 | 91   | 100.0 |

Note: f = frequency, % = percentage

### 3.3 Knowledge Retention and Conceptual Understanding

To further examine learning outcomes, eight multiple-choice questions addressing key laboratory quality management topics were included in both pre- and post-tests. These questions covered areas such as employee competency and training, equipment calibration, non-conformity, continuous improvement and customer-related aspects of quality management. As shown in Table 3, the test group demonstrated a marked increase in correct responses, with the average percentage of correct answers rising from 65.4% in the pre-test to 82.7% in the post-test. Improvements were observed across most question categories, indicating enhanced retention and application of course content following participation in the board game-based learning activities. In contrast, the control group showed relatively stable performance, with minimal variation between pre- and post-test scores. This suggests that while conventional instruction supported basic comprehension, it was less effective in reinforcing applied understanding and recall of specific quality management concepts. These findings reinforce the role of interactive learning environments in supporting meaningful knowledge retention.

Although inferential statistics were not applied due to the quasi-experimental design and unequal group sizes, the magnitude of improvement observed in the test group, particularly the increase in “Excellent” ratings and average correct responses, suggests practically meaningful learning gains when compared to conventional instruction.

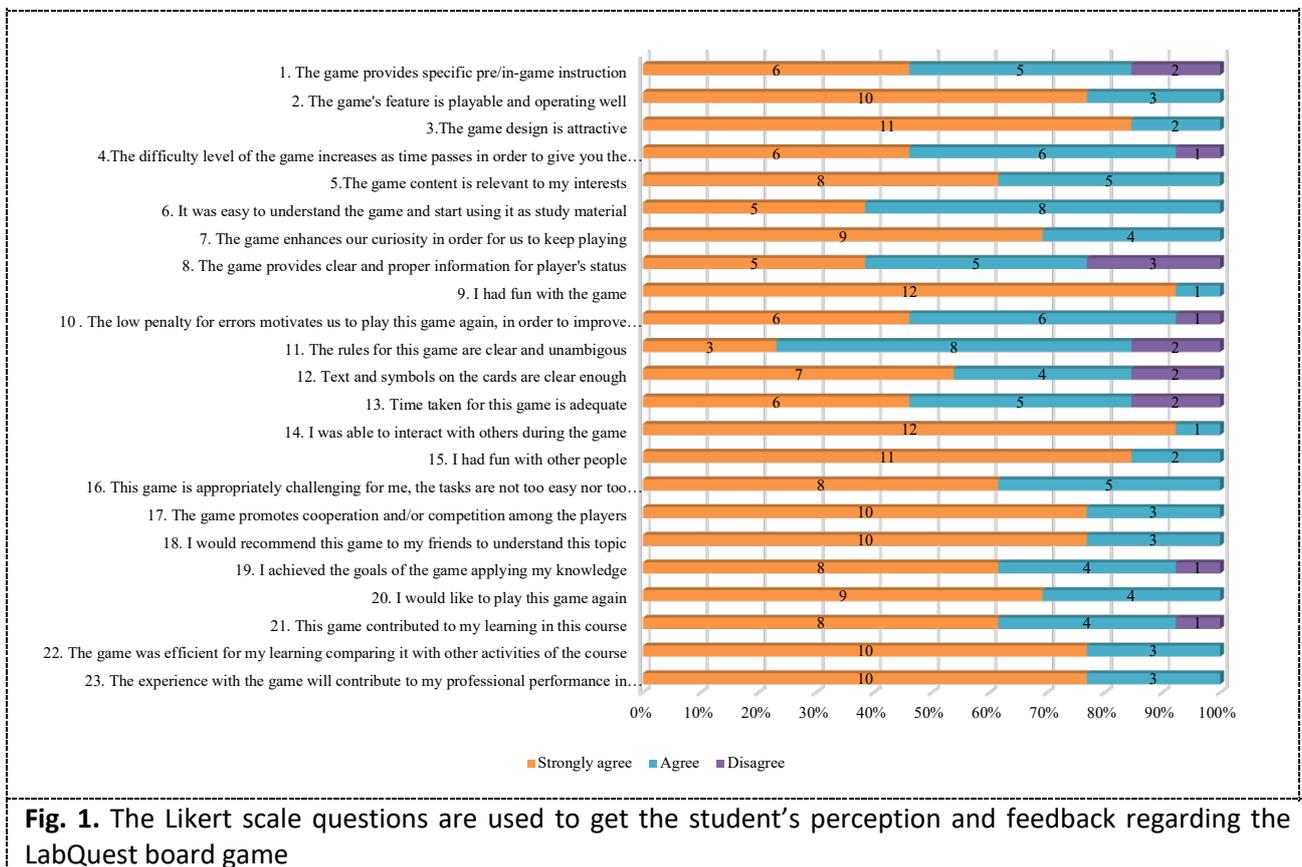
**Table 3**

Pre- and post-course evaluation on correct answer to multiple-choice questions

| Question No. | BSB (Control) |          | BSK (Include board game) |          |
|--------------|---------------|----------|--------------------------|----------|
|              | Pre (%)       | Post (%) | Pre (%)                  | Post (%) |
| 8            | 75.0          | 92.9     | 92.3                     | 92.3     |
| 9            | 96.4          | 82.1     | 53.8                     | 100.0    |
| 10           | 89.3          | 89.3     | 92.3                     | 100.0    |
| 11           | 3.6           | 0.0      | 0.0                      | 7.7      |
| 12           | 89.3          | 89.3     | 84.6                     | 100.0    |
| 13           | 60.7          | 67.9     | 69.2                     | 92.3     |
| 14           | 92.9          | 82.1     | 69.2                     | 69.2     |
| 15           | 82.1          | 78.6     | 61.5                     | 100.0    |
| Average (%)  | 73.7          | 72.8     | 65.4                     | 82.7     |

### 3.4 Student Perceptions of Engagement and Learning Experience

Students' perceptions of the board game-based learning experience were examined using Likert-scale questionnaires focusing on clarity, engagement, applicability and social interaction. The results, summarized in Figure 1, indicate a generally positive student response toward the use of LabQuest as a learning tool.



**Fig. 1.** The Likert scale questions are used to get the student's perception and feedback regarding the LabQuest board game

Most students strongly agreed that the board game enhanced their learning experience and was relevant to the course content. High levels of agreement were also reported for items related to enjoyment and engagement, with over 90% of students indicating that they enjoyed playing the game and found it engaging. These findings suggest that the game successfully captured students' attention and sustained their interest throughout the learning activity. Social interaction emerged as a particularly strong dimension, with most students strongly agreeing that the game promoted discussion, cooperation and interaction with peers. This supports the premise that board game-based learning encourages collaborative learning behaviours, which are essential for developing communication and teamwork skills in educational settings [13-15].

### 3.5 Clarity, Usability and Game Design Considerations

Responses related to clarity and usability revealed generally favourable perceptions, although some areas for improvement were identified. As shown in Table 4, many students agreed or strongly agreed that the game instructions were clear, the game components were functional and the overall difficulty level was appropriate. However, a smaller proportion of students expressed uncertainty regarding specific rules and card functions, suggesting the need for clearer explanations and

instructional support. These findings highlight the importance of instructional clarity in game-based learning interventions, as overly complex rules may detract from learning objectives if not adequately scaffolded.

**Table 4**  
 Total Likert scale responses

| Scale                 | Frequency | Percentage (%) |
|-----------------------|-----------|----------------|
| 1 (Strongly Disagree) | 0         | 0.0            |
| 2 (Disagree)          | 15        | 5.0            |
| 3 (Agree)             | 94        | 31.4           |
| 4 (Strongly Agree)    | 190       | 63.6           |
| Total                 | 196       | 100.0          |

### 3.6 Qualitative Insights into Learning and Engagement

Qualitative feedback from open-ended survey questions provided deeper insight into students' learning experiences. Responses to the question "If you would change anything in the game, what would it be?" were grouped into four main categories: instructions, game board, miniatures and game cards, as summarized in Table 5. Students commonly suggested clearer instructions, improved board markings and enhanced differentiation between game components, indicating areas for iterative refinement.

**Table 5**  
 Four main categories generated from the qualitative feedback by students

| Open-ended question  | Categories   | Feedback   |
|--|--------------|--|
| If you would change something in the game, what would it be? | Instructions | <ul style="list-style-type: none"> <li>• It takes too long for us to build a whole sector.</li> <li>• Maybe the instructions could be clearer.</li> <li>• Provide clear instructions.</li> <li>• The instructions are not well explained.</li> </ul>   |
|  | Game board   | <ul style="list-style-type: none"> <li>• I recommend placing a mark on the sector, so we can track when someone already buys the sector.</li> <li>• Differentiate between two same sectors on the board.</li> <li>• I think the calibration needs to have a price.</li> <li>• Want to have hijab girl personnel</li> <li>• The colour of the players, we should pay a fee for calibration and increase the money that we should pay to the owner when we stand on its sector.</li> </ul> |
|  | Miniatures   | <ul style="list-style-type: none"> <li>• For the chess pieces representing players, I would recommend different colours for better recognition.</li> <li>• There is a minute confusion regarding the card property of sectors, I wish there was a better explanation to clear the doubts.</li> </ul>   |
|  | Game card    | <ul style="list-style-type: none"> <li>• There are two same sectors but different prices when buying. However, the fee sector when other players need to pay the landlord has the same price, but the landlord pays a different price.</li> <li>• The punishment of reducing three personnel at a time costs too much.</li> <li>• Various training.</li> </ul>   |

Conversely, responses to the question "What did you like most about this game?" revealed five dominant themes: fun and engagement, design and aesthetics, learning and application, game mechanics and social interaction (Table 6). Thematic analysis produces fresh perspectives and

knowledge [16]. Students frequently described the game as enjoyable, visually appealing and helpful in understanding how quality management concepts operate in practice. Many responses emphasized the value of applying theoretical knowledge through gameplay, which aided memory retention and conceptual clarity [17]. These qualitative findings complement the quantitative results by demonstrating that the board game not only improved learning outcomes but also positively influenced students' motivation, engagement and collaborative behaviours [18].

**Table 6**  
 Themes generated from the qualitative feedback by students

| Open-ended question                     | Categories               | Feedback   |
|---|--------------------------|--|
| What did you like most about this game? | Fun and engaging         | <ul style="list-style-type: none"> <li>• Fun</li> <li>• The game concept is fun</li> <li>• The challenges</li> <li>• The board design is interesting</li> <li>• Want to have hijab girl personnel</li> </ul>   |
|   | Design and aesthetics    | <ul style="list-style-type: none"> <li>• I like the cute personnel and when buying sector</li> <li>• I like all aspects of the game. I like it when I buy sector, instrument, personnel and training because I become their CEO. All the illustrations are so pretty.</li> <li>• It helps me to understand more about the process and the knowledge about the instrument or the training that is suitable for our sector.</li> </ul> |
|   | Learning and application | <ul style="list-style-type: none"> <li>• When we can implement what we study in the game</li> <li>• The implementation of LQMV in a game makes us remember facts easier</li> <li>• I like the cute personnel and when buying sector</li> <li>• The presence of the rewards, non-conformity cards which make the game more enjoyable</li> </ul>   |
|   | Game mechanics           | <ul style="list-style-type: none"> <li>• Owning a sector and I really hope there's enough time for me to complete purchasing two sectors.</li> <li>• Becoming a banker and getting money from players through tax and non-conformity</li> <li>• The game was fun and we could interact with other people and revise what we learnt</li> </ul>  |
|   | Social interaction       | <ul style="list-style-type: none"> <li>• The arrangements</li> <li>• Identify what type of training is suitable with personnel</li> </ul>  |

Overall, the findings indicate that the integration of board game-based learning as a supplementary instructional strategy positively influenced students' understanding, engagement and perception of laboratory quality management education. The combination of improved post-test performance, positive student perceptions and rich qualitative feedback suggests that experiential learning through gameplay supports deeper learning processes compared to conventional instructional methods alone. By providing a structured yet interactive learning environment, LabQuest enabled students to engage in decision making, problem solving and peer discussion, which are critical components of effective learning in complex and procedural domains [19]. These results support the growing body of literature advocating game-based learning as an effective pedagogical approach for enhancing learning behaviour and outcomes in higher education [20].

### *3.7 Limitations and Implementation Considerations*

Several limitations should be considered when interpreting the findings of this study. First, measures of engagement and learning experience relied partly on self-reported data, which may be subject to social desirability or response bias. Second, learning outcomes were assessed over a relatively short instructional period; therefore, the results primarily reflect short-term learning gains rather than long-term knowledge retention or transfer.

Third, the observed improvements may be influenced by a novelty or Hawthorne effect, as students were exposed to a new and interactive learning activity that differed from their usual classroom experience. Additionally, although the instructor adopted a facilitative role during gameplay, instructor presence and guidance may have influenced student engagement and interaction. Finally, unequal group sizes and the use of a naturally occurring classroom setting limit the generalisability of the findings. These limitations reflect common constraints in educational research and highlight the need for cautious interpretation and further investigation.

In addition to methodological limitations, several practical considerations may influence the implementation of board game-based learning in higher education. These include the time required for gameplay within constrained class schedules, the initial cost of game materials, and the need for instructor familiarity with game facilitation strategies. Scalability may also present challenges in large class settings without sufficient facilitation support. Addressing these factors through modular game design, instructor training, and integration with existing curricula is essential to ensure sustainable adoption.

## **4. Conclusions**

This study examined the effectiveness of a board game-based learning intervention, LabQuest, in supporting students' understanding and engagement in laboratory quality management education. The findings demonstrate that students who participated in board game-assisted learning showed greater improvements in perceived understanding and objective knowledge measures compared to those receiving conventional instruction, alongside higher levels of engagement, collaboration, and interaction. From a theoretical perspective, these findings align with constructivist and experiential learning theories, which posit that knowledge is actively constructed through experience, social interaction, and reflection rather than passively received. The board game facilitated learning by situating abstract quality management concepts within simulated decision-making contexts, allowing students to test assumptions, experience consequences, and negotiate meaning collaboratively. This experiential structure helps explain why improvements were observed not only in engagement but also in applied understanding and retention. Rather than replacing traditional instruction, the use of LabQuest as a supplementary pedagogical scaffold, supporting the translation of theoretical concepts into practice. The structured gameplay encouraged discussion, problem solving, and peer learning, which are key mechanisms underlying meaningful learning in complex and procedural domains. While the findings are context-specific, they contribute to the social and behavioural sciences literature by demonstrating how structured, game-based learning environments can influence learning behaviour, motivation, and conceptual understanding in higher education. Future studies may build on this work by examining long-term learning effects, broader implementation contexts, and digital or hybrid adaptations of board game-based learning.

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