# WIP: Beyond the Classroom - Mystery Games as a Portal to SQL Proficiency

Sherif E. Abdelhamid
*Computer & Information Sciences*
*Virginia Military Institute*
Lexington, VA, USA
abdelhamidse@vmi.edu

Jacob Enfield
*Computer Game Design, CVPA*
*George Mason University*
Manassas, VA, USA
jenfield@gmu.edu

Vadapalli Swetha Annapoorna
*College of Engineering and Computing*
*George Mason University*
Manassas, VA, USA
vannapoo@gmu.edu

Ajay Kumar Addike
*College of Engineering and Computing*
*George Mason University*
Manassas, VA, USA
aaddike@gmu.edu

Tanner Mallari
*Computer & Information Sciences*
*Virginia Military Institute*
Lexington, VA, USA
mallaritp22@mail.vmi.edu

***Abstract*—This research-to-practice WIP paper outlines the development and implementation of an educational project to enhance SQL (Structured Query Language) learning through a series of mystery cases. The initiative underscores a novel approach to engaging undergraduate students in mastering SQL by integrating game-based learning within the curriculum. The theoretical frameworks underpinning this project are grounded in constructivist learning theories and the application of game-based learning in education. These frameworks suggest that learners construct knowledge more effectively when actively engaged in the learning process and when the learning is contextualized within meaningful and enjoyable activities. Unlike traditional methods of teaching SQL, which often emphasize memorization and passive learning, the SQL Mystery Game provides a dynamic platform for students to apply SQL concepts in a practical, engaging, and contextually rich setting. Students use their SQL skills to search for clues, filter out unwanted pieces of evidence, link data from multiple sources, and generate information from given data to solve different mysteries. The project builds on previous preliminary non-digital activities demonstrating positive student reception and instructor observations, suggesting that game-based learning can effectively enhance students' application of SQL concepts. Furthermore, the effectiveness of the new online game is evaluated using a user study that involved a multi-faceted survey designed to evaluate the game from various angles. The study results validated the efficacy of enhancing SQL learning through the SQL Mystery game and showed that it significantly improved students' engagement, interest, and understanding of SQL concepts. This research has significant implications for educational practice, particularly for engineering and computing education. It demonstrates the potential of game-based learning to transform passive learning environments into active ones, making complex subjects more accessible and enjoyable for students. This project offers valuable insights into designing engaging learning experiences that prepare students for real-world challenges and equip them with the skills necessary to thrive in data-intensive industries.***

***Keywords*—Game-based learning, Serious games, Constructivist, Active learning, Computer science,**

## I. Introduction

### A. Background and Motivation

In the digital age, proficiency in programming languages is needed, with SQL (Structured Query Language) recognized as a fundamental skill across various data-intensive domains. SQL's unique blend of declarative syntax with procedural elements presents a significant learning curve that can deter students, particularly those outside the core computer science discipline [1]–[3]. Traditional educational methods, which often rely on memorization and passive participation, are sometimes inadequate in equipping students with the practical skills necessary to navigate this complexity. As educators seek more effective pedagogical strategies, integrating engaging and innovative approaches within the curriculum is becoming increasingly vital. The motivation for developing games to promote learning of SQL stems from a critical observation: despite SQL's essential nature in the technological landscape, its instructional methods have not evolved to adequately address the challenges it presents. This project aims to enhance SQL education accessibility and engagement. It targets today's digital-native students, accommodating their preference for interactive, feedback-rich learning environments.

### B. Contributions

*1) Highlighting Under-explored Areas:* This project addresses a gap in SQL educational research. Despite its widespread application and recognition as a critical skill, few educational initiatives have focused on enhancing SQL learning through gamification or game-based learning. Our approach offers a new perspective on engaging students.

*2) Innovative Multi-Tier Architecture:* The online game developed for this project employs a multi-tier architecture, effectively separating the user interface from the data management components. This design enhances the system's extensibility and simplifies the integration of new mysteries and updates in the future.

*3) Comprehensive Student Survey:* An integral part of this project is executing a multi-faceted survey designed to evaluate the game from various angles, including usability, engagement, conceptual understanding, and educational impact.

## II. Related Works

Game-based Learning and Gamification have emerged as promising approaches to enhance learning experiences by integrating dynamics and mechanics to increase learner engagement and effectiveness [4], [5]. Dynamics, which provide the narrative, and mechanics, which implement the story, together incentivize learners through internal motivations such as personal achievement or desire for rewards, thereby potentially augmenting student engagement, effort, and satisfaction. Gamification in computer science education has been a topic of interest in recent research. Incorporating gamification elements into teaching and learning sessions for computer science or information technology courses has been shown to enhance student engagement and improve learning retention [6]. Game-based Learning has proven to be particularly beneficial in creating simulated learning environments that increase motivation among computer science students [7]. The success of gamification and game-based learning in educational settings depends significantly on factors such as student characteristics, their specific needs, and the thoughtful incorporation of gamified elements [4], [5]. Tailoring the strategies of the two approaches to match the preferences and culture of the student community is essential for optimal outcomes. Several studies have explored the integration of game-based learning and gamification in teaching SQL skills to enhance learning experiences. Tahir, Mitrovic, and Sotardi [8] incorporated badges within SQL-Tutor, a tutoring system, alongside goals, assessments, and challenges. While they observed that badges increased student engagement and time-on-task, they did not find a significant difference in post-test scores or student achievement levels. More promising, Tuparov and Tuporova [9] implemented badges and leaderboards in an online self-training course involving 97 students. Their findings indicated that gamification positively impacted student achievement within the gamified group compared to the non-gamified cohort. Furthermore, Soflano, Connolley, et al. [10] evaluated the impact of game-based learning on learning effectiveness and the effect of adapting learning content to students' learning styles. Results showed that game-based learning yielded better learning outcomes than learning from a textbook and that adaptive learning allowed students to finish tasks much faster than non-adaptive mode. These studies collectively highlight the potential of gamification and game-based learning to improve the learning outcomes of SQL education. However, others have pointed out potential adverse effects, emphasizing the importance of a nuanced understanding of its implementation [11]. The possible additional workload on teachers and lack of customization and personalization for students can cause some challenges [12]. The SQL Mystery game aims to bridge some of the identified challenges in the related literature. Firstly, unlike previous studies that primarily focused on incorporating badges and leaderboards into existing tutoring systems or online courses (i.e., gamification), the SQL Mystery game provides a unique experience where students actively engage in solving mysteries using their SQL skills (i.e., game-based learning). Embedding SQL challenges within a narrative-driven mystery framework offers a compelling storyline as the primary dynamic, encouraging sustained engagement and motivation. Additionally, the game can provide an online platform for instructors to customize and adapt SQL challenges based on their student's specific needs and skill levels. This is achievable because of the multi-tier architecture and the separation of data from the user interface. New customized stories and challenges can be easily added in the future based on the target student population. Finally, the study examines the usability aspects of the system to avoid any technical challenges that might affect the student's learning experience. Ensuring good usability testing processes during the development of gamification systems is essential to maintain their motivational effects [13].

## III. Theoretical framework

### A. Digital Game-based Learning

Egenfeldt-Nielsen's book [14] provides a history and discussion of *Digital Game-based learning* (DGBL), *Game-based Learning* (GBL), and *Serious Games*. Briefly, Serious Games include any games with a primary purpose other than entertainment, including games for health, games for change, and games for learning. Serious games may be in any format, including board, dice, card, and video games. GBL focuses on serious games that are designed to promote learning, including games for training and education. DGBL focuses on digital games designed to promote learning.

There have been many theories related to DGBL supported by evidence at varying degrees. Some theories and research attempt to explain how video games achieve high levels of engagement. For example, Csíkszentmihályi's theory of Flow [15] is often used to explain the phenomenon of gamers becoming so engrossed in gameplay that time passes without notice and everything outside of the game seems to fade from the mind. To achieve flow, designers must balance the level of challenge in gameplay with the player's ability level. Koster [16] explains games' inherently engaging and intrinsically motivating nature through game design. Specifically, Koster suggests that designs that harness skills that humans have evolved to enjoy and be good at, i.e., pattern recognition, will be effective as long as the challenge increases along with the player's skill.

Other theories and research attempt to identify affordances of DGBL that could promote learning, including tracking player performance and providing just-in-time information or interventions to support learning. Another affordance that is touted as increasing engagement, and therefore time-on-task and learning, is the ever-increasing level of immersion resulting in virtual reality and other technological advances that allow video games to reach high levels of realism. Games are also thought to align with *Constructivist* learning theory, allowing learners to construct their own knowledge through

experience. Indeed, games allow players to explore and try out strategies in a low-risk environment that reduces anxiety while enhancing creativity.

Still, other theories are prescriptive in nature, describing how games could be designed following instructional design models to best achieve learning objectives. For example, Enfield [17] investigated how the *Ten Steps to Complex Learning* Instruction Design Theory could be applied to the design of a game intended to promote learning.

### B. Reaching Potential for Game-Based Learning

GBL will never be a silver bullet for learning. As a lesson from the Clark [18] and Kozma [19] debates, it is more worthwhile to focus on the learning experience than whether or not a particular medium is effective for learning. Indeed, games can be well-designed or poorly designed to meet their objectives. The question is not "Are games good for learning?" but "How can games best be used to promote learning"?

The SQL Mystery game embraces many of the proven strategies that lead players to achieve learning objectives. In addition to implementing some of the affordances already discussed (creating an engaging context that provides learners with a low-risk environment to apply their skills), It provides a simulated real-world context in which learners may apply their skills to solve an authentic problem, at least within the simulated context of the game world. Additionally, the game incorporates common components of games that enhance engagement, such as story, goals, points, and increasing levels of challenge.

### C. Debriefing

The implementation of the SQL Mystery game within a classroom also followed proven best practices. Specifically, the instructor guided students in a debriefing exercise after gameplay. Egenfeldt-Nielsen [14] notes the importance of debriefing in linking learning objectives to gameplay. Because games often provide learners with a shared experience and sometimes slightly varied experiences due to varied gameplay, debriefing allows for identifying misconceptions learned through gameplay. Possibly, the most important aspect of debriefing is reflection–providing students the time to reinforce their existing mental models or modify those models to accommodate the newly learned information.

## IV. System Design

This section discusses the SQL Mystery Game's architecture and the main interactions, as shown in Fig. 1, between its system components and the primary entities—students and teachers—that facilitate a dynamic learning environment. Upon initiation, users are welcomed by a narrative that outlines the storyline and its progression. This introduction is critical as it sets the stage for the mystery they are tasked to solve. Following the narrative immersion, players are prompted to log in. The login module, as described in the data flow diagram, is designed to authenticate users and maintain the integrity of player progress and scores. Upon successful login, an auto-generated email notification is sent to the teacher associated with the student. This step ensures that each session is conducted under appropriate academic supervision. Central

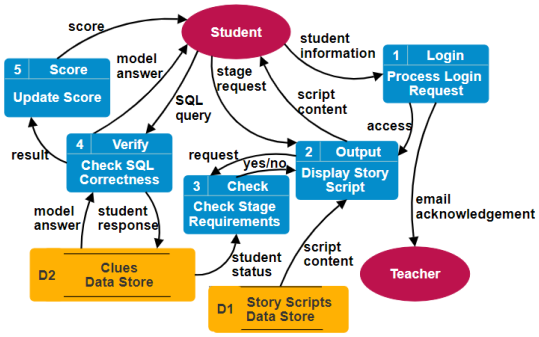


Fig. 1. SQL mystery game main processes and data stores.

to the gameplay is the SQL-driven database, which stores game data, including story scripts, clues, and the expected correct answers. As players advance through the game, they encounter a series of questions designed to challenge their SQL skills. Each correctly answered question makes them closer to solving the mystery and reinforces SQL concepts in a practical context; see Fig. 2. The game provides a hint feature to help in the learning process. The integration of hints was motivated by similar approaches in related literature [20]. The separation of the database and the front-end code is a pivotal feature of the game's design. This multi-tier design allows the addition of new scenarios and stages to the game with less effort and fewer changes to the front end. The game's scoring system is crucial for maintaining engagement and introducing a competitive element among players. As players answer more questions correctly, their scores increase and they can advance to the next level.

## V. Research Methodology

### A. Phase one

The study started with a fifteen-minute session to introduce the eleven participants to the game and provide an overview of the game's objectives and mechanics. Following the introduction, participants were asked to play the mystery game in teams for forty-five minutes. During the game, students had to solve three cases. The first two mystery cases were provided through the university learning management system (LMS). Students had to download a file containing the suspect's names, set up the MySQL database, and run the needed queries to solve the mysteries. For the last case, students used our online game (SQL Mystery) platform, responded to the provided instructions, and constructed the needed queries using the built-in query builder.

### B. Phase two

A survey was conducted to gather feedback from students regarding their experience with the SQL mystery game. The survey was designed to assess various aspects of the game, including its effectiveness in enhancing SQL learning, engagement value, and usability.

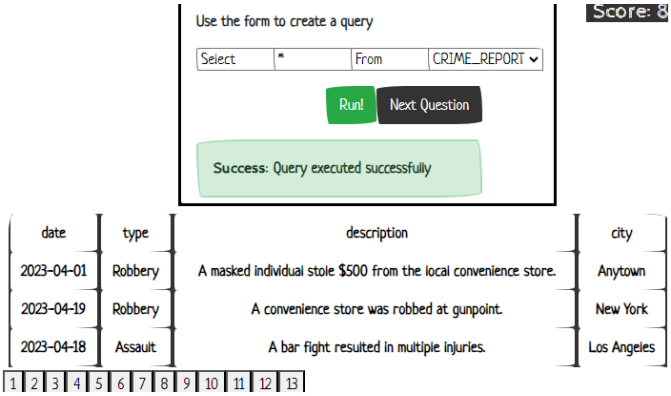


Fig. 2. SQL mystery game screenshot showing the query builder, query results, and current student score. In this screen, students use their SQL skills to navigate the crime report, collect pieces of evidence, and construct the knowledge needed to solve the mystery. This example shows the interplay between constructivist learning theory and specific game design elements.

*1) Survey Design:* The survey instrument, shown in Table I, was designed to collect quantitative and qualitative data. It included a combination of closed-ended questions with Likert-scale responses to measure satisfaction levels and open-ended questions to gather detailed feedback and suggestions for improvement.

*2) Sampling:* The survey's target population was undergraduate computer science majors registered in the database management course at Virginia Military Institute (VMI).

*3) Data Collection and Analysis:* The survey was administered electronically using an online survey platform (Qualtrics) to ensure participants' ease of access and anonymity. The survey link was distributed to students via the course learning management system and the participation rate was 100%.

*4) Data Analysis:* Quantitative data collected through Likert-scale questions is analyzed using descriptive statistics to measure central tendencies and variability in students' responses. Qualitative data from open-ended questions is analyzed thematically to identify main themes.

*5) Ethical Considerations:* The research adhered to ethical guidelines for human subjects research. Participants were informed about the purpose of the survey and their rights as research subjects. The Institutional Review Board (IRB) at the Virginia Military Institute (VMI) reviewed, validated, and approved the study. The survey questions were checked for internal consistency and correlation.

*6) Limitations:* Potential limitations may include self-report bias, small sample size, and limited generalizability of findings beyond the study's specific context.

## VI. Initial Results and Discussions

The analysis of the students' responses aims to dissect both the quantitative and qualitative data collected and provide insights into the game's engagement levels, educational effectiveness, and areas for potential enhancement. The feedback obtained not only highlights the game's strengths in maintaining interest and reinforcing SQL concepts but also points out opportunities for further development to meet students' learning needs better.

### A. Quantitative Insights

*1) Engagement:* The game was generally well-received in terms of engagement, with an average rating of 4.64 out of 5. This high level of engagement is further supported by the low standard deviation (0.64), indicating that most responses were close to the mean and consistently positive.

*2) Positive Feedback:* The students most liked the game's engaging nature, competitive elements, visual simplicity, and interactive features like the ticking clock and the use of drop-down menus instead of free-form SQL input.

*3) Criticism and Suggestions:* Some students felt the game lacked visual aids. Improvement suggestions included increasing the difficulty by adding higher levels, enhancing visual design, and integrating more interactive SQL environments like MySQL workbench.

*4) Learning Effectiveness:* Students rated the game quite highly for reinforcing SQL concepts learned in class, with an average rating of 4.27 out of 5. This suggests the game served as a practical tool beyond traditional methods, which is also seen in the majority preferring the game over traditional assignments.

*5) Usability:* The user interface was deemed easy to use, with a mean score of 4.36 out of 5. Only one student experienced significant technical issues, indicating good platform stability.

*6) Motivation and Interest:* All students reported increased interest in learning more about SQL due to the game. The mystery-solving aspect was particularly motivating, averaging a 4.55 out of 5 in terms of encouraging learning through SQL.

*7) Challenge Level:* The difficulty level was moderately rated, with an average score of 3.82 out of 5. This suggests that while the game was not overly challenging, it was not trivial either, balancing engagement with cognitive demand. Improvement suggestions included increasing the difficulty level of the game.

*8) Strategic Thinking:* The majority felt that the game effectively taught them to approach SQL problems strategically, which is essential for learning any programming language. 10 out of 11 students selected "Yes".

*9) Future Enhancements:* Students' suggestions for future topics include more advanced SQL operations like grouping queries, creating and dropping tables, and joining operations, as well as possibly integrating other programming skills such as HTML or JavaScript.

### B. Qualitative Insights

*1) Engagement and Motivation:* Key game elements that maintained interest included the game's plot, the urgency created by a ticking clock, and incentives like extra credit.

*2) Educational Value:* The different scenarios presented helped illuminate SQL concepts, although some students noted a gap in understanding joins.

### C. Interface and Accessibility

While praised for its simplicity and reliability, some students felt the game's design could be more visually engaging and suggested that hints could be provided after incorrect submissions.

TABLE I
SURVEY QUANTITATIVE QUESTIONS

| Category | Question | Type | Avg. Score | Std. Dev. |
|---|---|---|---|---|
| **Engagement and Experience** | How engaging did you find the SQL Mystery game? 1 being not engaging at all, 5 being very engaging | Likert Scale 1 to 5 | 4.64 | 0.64 |
| **Learning and Effectiveness** | How helpful was the game in providing an opportunity to reinforce the SQL concepts learned in class? 1 being not well at all, 5 being very well | Likert Scale 1 to 5 | 4.27 | 0.75 |
| **Learning and Effectiveness** | How likely are you to recommend the SQL Mysteries game to a friend or classmate? (1 to 5) 1 being unlikely, 5 being very likely | Likert Scale 1 to 5 | 4.36 | 0.64 |
| **Learning and Effectiveness** | How do you see the game's effectiveness in helping you practice SQL compared to traditional assignments or exercises? 1 being traditional methods are much more effective, 5 being the SQL mystery game or similar games are much more effective | Likert Scale 1 to 5 | 4.27 | 0.96 |
| **Usability and Ease of Use** | How would you rate the overall user interface and design of the SQL Mysteries game? 1 being very difficult to use, 5 being very easy to use | Likert Scale 1 to 5 | 4.36 | 0.64 |
| **Usability and Ease of Use** | Did you encounter any technical issues while using the platform? | Multiple Choices | Yes: 1<br>No: 9<br>Somewhat: 1 | |
| **Motivation** | Did the game's activity increase your interest in learning more about SQL and database management? | Multiple Choices | Yes: 11<br>No: 0<br>Somewhat: 0 | |
| **Motivation** | How motivating was the mystery-solving aspect of the game for learning SQL? 1 being not motivating at all, 5 being very motivating | Likert Scale 1 to 5 | 4.55 | 0.66 |
| **Problem-Solving Skills** | How challenging were the problems presented in the SQL Mysteries game? 1 being very difficult to solve, 5 being very easy to solve | Likert Scale 1 to 5 | 3.82 | 0.83 |
| **Problem-Solving Skills** | Do you think the games were effective in teaching you to approach SQL problems strategically? | Multiple Choices | Yes: 10<br>No: 0<br>Somewhat: 1 | |

## VII. CONCLUSIONS AND FUTURE WORK

This study validates the efficacy of enhancing SQL learning through the Mystery game, which significantly improved students' engagement and understanding of SQL concepts. Planned upgrades include advanced SQL features, better visuals, and automated hints. Future research will involve larger, more diverse student groups and encourage other teachers to adopt the game across more courses, guiding its ongoing development and aiding similar game designs.


## ACKNOWLEDGMENT

This research was funded by 4-VA, a collaborative partnership for advancing the Commonwealth of Virginia.


## REFERENCES


[1] S. Sadiq, M. Orlowska, W. Sadiq, and J. Lin, "Sqlator: an online sql learning workbench," in *Proceedings of the 9th annual SIGCSE conference on Innovation and technology in computer science education*, 2004, pp. 223–227.

[2] T. Taipalus, M. Siponen, and T. Vartiainen, "Errors and complications in sql query formulation," *ACM Transactions on Computing Education (TOCE)*, vol. 18, no. 3, pp. 1–29, 2018.

[3] S.-S. Shin, "Structured query language learning: Concept map-based instruction based on cognitive load theory," *IEEE Access*, vol. 8, pp. 100 095–100 110, 2020.

[4] D. Zhao, C. H. Muntean, A. E. Chis, G. Rozinaj, and G.-M. Muntean, "Game-based learning: enhancing student experience, knowledge gain, and usability in higher education programming courses," *IEEE Transactions on Education*, vol. 65, no. 4, pp. 502–513, 2022.

[5] A. Stott and C. Neustaedter, "Analysis of gamification in education," *Surrey, BC, Canada*, vol. 8, no. 1, p. 36, 2013.

[6] N. Z. M. Safar, H. Kamaludin, M. Ahmad, M. H. Jofri, N. Wahid, and T. Gusman, "Intervention strategies through interactive gamification e-learning web-based application to increase computing course achievement," *JOIV: International Journal on Informatics Visualization*, vol. 6, no. 2, pp. 376–381, 2022.

[7] S. Erhel and E. Jamet, "Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness," *Computers & education*, vol. 67, pp. 156–167, 2013.

[8] F. Tahir, A. Mitrovic, and V. Sotardi, "Investigating the effects of gamifying sql-tutor," in *Proceedings of the 28th International Conference on Computers in Education*. Asia-Pacific Society for Computers in Education, 2020.

[9] G. Tuparov and D. Tuparova, "Gamification in higher education-a pilot study with sql course." in *ERIS*, 2021, pp. 81–90.

[10] M. Soflano, T. M. Connolly, and T. Hainey, "An application of adaptive games-based learning based on learning style to teach sql," *Computers & Education*, vol. 86, pp. 192–211, 2015.

[11] R. Oktaviati and A. A. Jaharadak, "The impact of using gamification in learning computer science for students in university," *International Journal of Engineering & Technology*, vol. 7, no. 4.11, pp. 121–125, 2018.

[12] D. Zhao, J. Playfoot, C. De Nicola, G. Guarino, M. Bratu, F. Di Salvadore, and G.-M. Muntean, "An innovative multi-layer gamification framework for improved stem learning experience," *IEEE Access*, vol. 10, pp. 3879–3889, 2021.

[13] D. Dicheva, K. Irwin, and C. Dichev, "Oneup: Supporting practical and experimental gamification of learning," *International Journal of Serious Games*, vol. 5, no. 3, pp. 5–21, 2018.

[14] S. Egenfeldt-Nielsen, B. Meyer, and B. H. Sørensen, *Serious games in education: A global perspective*. Aarhus Universitetsforlag, 2011.

[15] M. Csikszentmihalyi and M. Csikzentmihaly, *Flow: The psychology of optimal experience*. Harper & Row New York, 1990.

[16] R. Koster, *Theory of fun for game design*. " O'Reilly Media, Inc.", 2013.

[17] J. Enfield, "Designing an educational game with ten steps to complex learning," Ph.D. dissertation, Indiana University, 2012.

[18] R. E. Clark, "Media will never influence learning," *Educational technology research and development*, vol. 42, no. 2, pp. 21–29, 1994.

[19] R. B. Kozma, "Will media influence learning? reframing the debate," *Educational technology research and development*, vol. 42, no. 2, pp. 7–19, 1994.

[20] D. Lavbič, T. Matek, and A. Zrnec, "Recommender system for learning sql using hints," *Interactive Learning Environments*, vol. 25, no. 8, pp. 1048–1064, 2017.