Escape Rooms as an Educational Tool for Engineering Education: Implementation of an Educational Chemical Engineering Escape Room

Alejandra Torres-Velasco[a] and Abhishek Juneja[b]
The University of Kansas, Department of Chemical and Petroleum Engineering[a],
Department of Educational Psychology[b]

Abstract

Escape rooms have emerged as innovative educational tools in various disciplines, including engineering education, due to their potential to engage students in active learning and problem-solving. This paper explores the application of escape rooms as an educational tool in engineering education, with a specific focus on a Chemical Engineering Escape Room developed for implementation at the 2024 ASEE Midwest Section Conference. The Chemical Engineering Escape Room was conceptualized to provide participants with an immersive learning experience while reinforcing key concepts in chemical engineering. A significant aspect of its development involved the use of MATLAB for programming virtual riddles and clues, enhancing practicality, portability and reducing implementation costs. To guide participants through the game and ensure educational outcomes were met, learning tools in the form of educational brochures were created. These brochures outlined the flow of the escape room and provided succinct explanations of the core educational concepts embedded within the puzzles. Post-activity questionaries were designed to evaluate the effectiveness of chemical engineering escape rooms as an alternative pedagogic method. This data will be collected at the 2024 ASEE Midwest Section Conference, and the results would be discussed in a separate manuscript. Hence, this study serves as the foundation of our work in the future, highlighting the versatility of escape rooms across various engineering concepts. Therefore, the goal is to establish Chemical Engineering Escape Rooms as an example of a collaborative and creative approach to engineering education, leveraging gamification and immersive storytelling to enhance learning experiences outside traditional classroom settings. The integration of virtual programming and educational brochures underscores the adaptability and scalability of escape rooms as tools for promoting active learning and knowledge retention among engineering students.

Keywords

Escape room, engineering education, active learning, gamification, chemical engineering.

Introduction

In recent years, the field of engineering education has seen a growing interest in innovative teaching methods that can enhance student engagement, promote active learning, and develop critical thinking skills. The immersive nature of escape rooms engages participants in active learning, problem-solving, and teamwork, making them conducive to fostering critical thinking skills and knowledge retention [1], [2]. Among these methods, educational escape rooms have emerged as a promising tool, capturing the attention of educators and researchers alike [3]. This paper explores the implementation of escape rooms as an educational tool in engineering education, with a particular focus on a Chemical Engineering Escape Room developed for the 2024 ASEE Midwest section conference.

Educational escape rooms are immersive, game-based learning experiences where participants solve a series of puzzles and challenges within a time limit to achieve a specific goal, typically "escaping" a themed room [4]. In the context of engineering education, these experiences have been shown to offer numerous advantages. Borrego et al. [5] demonstrated that escape rooms can significantly increase student motivation and engagement in computer science courses. Similarly, Fotaris and Mastoras [1] observed improvements in problem-solving, critical thinking, and teamwork skills among engineering students who participated in educational escape rooms.

The integration of escape rooms into engineering curricula is particularly noteworthy for disciplines like chemical engineering, where theoretical concepts can be complex and abstract. By embedding these concepts into puzzles and challenges, escape rooms provide students with hands-on experiences that bridge the gap between theory and practice [6]. This approach not only reinforces learning but also promotes critical thinking and problem-solving skills essential for engineering professionals [7].

The application of escape rooms in chemical engineering education has gained traction in recent years. Dietrich [8] pioneered the use of an escape room to teach the Leblanc process, demonstrating its effectiveness in enhancing student understanding of complex chemical processes. In a similar direction, Herrera et al. [9] created a digital escape game for teaching chemical engineering to first-year students, highlighting the potential of virtual formats in this field.

The versatility of escape rooms in teaching various engineering subjects has been well-documented across disciplines. In computer science, Otemaier et al. [10] successfully used an escape room to teach mathematical logic, while Magreñán et al. [11] implemented a digital escape room setting for teaching calculus.

Despite these advantages, the implementation of educational escape rooms is not without challenges. Veldkamp et al. [12] discussed the time and resource constraints faced by educators when developing and running these activities. Additionally, Taraldsen et al. [13] emphasized the importance of balancing entertainment and educational value in puzzle design, a crucial consideration for effective implementation.

Specific to the domain of engineering, Tejado et al. [14] developed an escape room focused on process control, demonstrating its effectiveness in improving student engagement and understanding of complex concepts. Similarly, de la Flor et al. [15] created an educational lab-escape room for teaching heat transfer concepts in chemical engineering, highlighting the potential of this approach in addressing interdisciplinary topics. While traditional escape rooms require physical setups, recent advancements have facilitated the development of virtual escape rooms, leveraging technologies such as MATLAB for programming riddles and clues. This virtual approach enhances flexibility, scalability, and cost-effectiveness, making escape rooms more accessible to educational institutions with limited resources [16].

Responding to the challenges and building upon the existing body of research, we have developed a Chemical Engineering Escape Room that leverages virtual elements programmed in MATLAB. This approach aims to create a more practical and cost-effective solution while maintaining the engaging aspects of traditional escape rooms. Our design integrates educational brochures to provide participants with game flow guidance and concise explanations of the underlying engineering principles, addressing the need for clear educational objectives [17].

The escape room will be implemented at the upcoming 2024 ASEE Midwest section conference, where we plan to gather data gauging its effectiveness through a post-activity questionnaire. However, the analysis of learning outcomes will be addressed in a separate manuscript, as the scope of this paper primarily focuses on the conceptualization, design, and integration of the escape room as an educational tool within the field of chemical engineering.

By combining the proven benefits of educational escape rooms with a novel virtual approach, our study aims to contribute to the growing body of knowledge on innovative teaching methods in chemical engineering education. We seek to demonstrate how technology can be leveraged to create relatively simple, engaging, cost-effective, and scalable educational experiences that foster the development of crucial engineering skills.

Methods

Literature Review:

- Conducted a comprehensive review of peer-reviewed articles on educational escape rooms in engineering and STEM fields.
- Analyzed benefits, challenges, and best practices in implementing educational escape rooms.

Chemical Engineering Escape Room Development:

- Designed a virtual escape room focusing on key chemical engineering concepts.
- Programmed riddles and clues using MATLAB to ensure practicality and cost-effectiveness.
- Created educational brochures to guide participants through the game flow and provide brief descriptions of key learning concepts.

Implementation:

- Deployed the escape room at the ASEE Midwest section conference.
- Participants included engineering students and educators.

Assessment:

- Developed post-activity questionnaire to measure the learning outcomes.
- The questionnaire covered questions related to content, pedagogy as well as the overall feedback of the learning experience.

Data Analysis:

- Data collected through administering the scale will be analyzed to understand the overall effectiveness of escape rooms as a learning method for teaching chemical engineering concepts.
- Specific insights will be discussed in our future work, in terms of content and pedagogy, to determine the value of escape rooms in contributing towards learning chemical engineering concepts.

It is important to highlight that the application of the post-activity questionnaire and data collection will be executed at the upcoming 2024 ASEE Midwest Section Conference. Therefore, the data analysis section will be discussed in future work**.**

Results

Comprehensive Review of Educational Escape Rooms in Engineering and STEM Fields

Educational escape rooms have gained significant attention in recent years as an innovative teaching tool in engineering and STEM fields. This review synthesizes findings from peer-reviewed articles, analyzing the benefits, challenges, and best practices in implementing educational escape rooms.

Benefits:

1. Enhanced Engagement and Motivation: Numerous studies have reported increased student engagement and motivation when using escape rooms in engineering education. Vörös and Sárközi [3] found that physics escape rooms significantly improved student motivation. Similarly, Borrego et al. [5] observed heightened engagement in computer science courses utilizing escape room activities.
2. Improved Problem-Solving and Critical Thinking Skills: Escape rooms have been shown to enhance problem-solving and critical thinking abilities. Fotaris and Mastoras [1] reported substantial improvements in these skills among engineering students participating in educational escape rooms. López-Pernas et al. [18] corroborated these findings in their study of computer engineering students.
3. Teamwork and Communication Skills Development: The collaborative nature of escape rooms fosters teamwork and communication skills. Hermanns et al. [19] noted improved collaboration among students in their pharmacy education escape room, a finding that can be extrapolated to engineering contexts.
4. Knowledge Retention: Studies have indicated that escape rooms can lead to better knowledge retention. Eukel et al. [20] found that pharmacy students who participated in an educational escape room demonstrated superior knowledge retention compared to those who received traditional lectures.
5. Interdisciplinary Learning: Escape rooms offer opportunities for interdisciplinary learning. Dietrich [8] successfully used an escape room to teach chemical engineering principles, demonstrating how these activities can integrate multiple STEM concepts. However, our study is distinct in terms of implementation and design. First, we are implementing our study with college students and educators instead of working with high

school students. Second, Dietrich [8] worked with paper-based puzzles, termed as "enigmas" and high school students were supposed to solve one after the other to proceed. Instead of paper-based puzzles, we are incorporating adaptable technology to make the escape room flexible, portable and immensely easy to set up and finally, we are extending our study to observe whether we can teach other concepts, besides Leblanc Process which is the concept covered by Dietrich [8], through the application of escape room as an alternative pedagogic method.

Challenges:

1. Time and Resource Constraints: Developing and implementing escape rooms can be time-consuming and resource intensive. Veldkamp et al. [12] highlighted these constraints as significant challenges for educators.
2. Balancing Entertainment and Education: Maintaining an appropriate balance between entertainment and educational content is crucial. Makri et al. [17] emphasized the importance of careful design to ensure that learning objectives are not overshadowed by game elements.
3. Scalability: Escape rooms typically work best with small groups, which can be challenging in large class settings. Taraldsen et al. [13] noted this as a potential drawback in their review.
4. Assessment Difficulties: Developing standardized assessment methods for escape room activities can be challenging. Gómez-Urquiza et al. [21] discussed this limitation in the context of nursing education, but it applies equally to engineering fields.

Best Practices:

1. Aligning with Learning Objectives: Nicholson [4]stressed the importance of aligning puzzle design with specific learning objectives to maximize educational value.
2. Incorporating Feedback Mechanisms: Incorporating immediate feedback within the escape room experience can enhance learning. Clarke et al. [22] demonstrated the effectiveness of this approach in their educational escape room framework.
3. Utilizing Technology: Leveraging technology can enhance the escape room experience and make implementation more feasible. Magreñán et al. [11]developed a digital escape game for engineering degrees that showcased the potential of technology in this context.
4. Providing Clear Instructions and Goals: Clear instructions and well-defined goals are essential for a successful educational escape room. Tejado [14] emphasized this in their process control escape room for engineering students.
5. Post-Activity Debriefing: Conducting thorough debriefing sessions after the escape room activity helps reinforce learning. De la Flor et al. [15] incorporated this practice in their heat transfer-focused escape room for chemical engineering education.

Thus, educational escape rooms offer numerous benefits for engineering and STEM education, including enhanced engagement, improved problem-solving skills, and better knowledge retention. However, challenges such as resource constraints and scalability need to be addressed. By following best practices like aligning puzzles with learning objectives and incorporating technology, educators can maximize the effectiveness of these innovative teaching tools.

Escape Room Design

Objective:

The primary goal of this Chemical Engineering Escape Room is to identify a toxic compound being released in the room and stop its release within a 30-minute time limit. Participants must solve a series of riddles and games that incorporate key chemical engineering concepts.

Escape Room Structure:

The escape room consists of five main activities that involve all the key concepts. An explanation of each activity will be given below. In addition, screenshots of the game applications programmed for the activities will be presented in the appendices of the document.

Figure 1. Starting graphical interface of the escape room.

1. Finding the Secret Chemical Compounds

- Setting: Digital display with a water-filled tank with temperature control
- Task: Reveal hidden chemical formulas written on the inner wall of the tank
- Key Concept: Thermodynamics and phase changes
- Solution: Increase water temperature above 100°C to cause liquid-to-gas phase change for water under pressure condition of 1 atm
- Outcome: Reveal formulas for NaCl, CO, HO, HCl

2. Forming Compounds

- Setting: Digital display with 5 Erlenmeyer flasks
- Task: Combine flasks to form the compounds discovered in step 1
- Key Concept: Atomic numbers and chemical element identification
- Process: Match flasks (labeled with atomic numbers) to form two-element compounds
- Outcome: Each correct combination lights a bulb with a unique color

3. Identifying the Toxic Chemical

- Setting: Digital display with color picker boxes to assign the colors of the compounds previously found
- Task: Assign the colors from step 2 to the respective compounds to identify the toxic substance
- Key Concept: Safety Square (NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response)
- Outcome: Find the identity of the toxic gas been released

4. Locating the Key to Stop the Release

- Setting: A digital display with a text box asking for the name of the toxic compound, a locker physically located in the room containing a secret object (gallon of water)
- Task: Input toxic compound name and health hazard level to reveal a numeric code
- Key Concept: Archimedes' principle and buoyant force
- Process: Use water from the locker to float a Styrofoam ball located out of reach at the bottom of a long cylinder located in the room
- Outcome: Retrieve final key message (PV=nRT) from inside the floating Styrofoam ball

5. Stopping the Release

- Setting: A digital display with an ideal gas law problem
- Task: Input the final key message, the ideal gas law equation and the answer for a simple related problem to stop the toxic release
- Key Concept: Ideal gas law
- Outcome: Completion of the escape room

Time Constraint:

Participants have 30 minutes to complete all tasks before toxic levels reach the maximum allowed limit.

Additional Components:

1. Game Flow Brochure: Provides clues and guides participants through the escape room
2. Educational Brochure: Explains key concepts involved in each step

Brochures are included in the appendix section of the manuscript.

Key Concepts

Fundamental chemical engineering concepts such as the laws of thermodynamics, atomic structure, toxic compound identification, Archimedes' principle, and the ideal gas law form the cornerstone of the discipline. Thermodynamics governs energy transfer and chemical reactions, while atomic structure underlies material properties and chemical behavior. Toxic compound identification is crucial for safety and environmental protection in chemical processes.

Archimedes' principle, fundamental to fluid mechanics, has applications in various engineering designs. The ideal gas law (PV=nRT) provides a foundation for understanding gas behavior in numerous processes. These interconnected concepts, among others, are essential for process design, optimization, and safety in chemical engineering. They enable engineers to predict and control chemical reactions, design efficient systems, ensure safe handling of materials, and understand complex fluid and gas behaviors. By incorporating these principles into an escape room scenario, participants engage with these crucial concepts in a practical, hands-on manner, reinforcing their theoretical knowledge and demonstrating the real-world relevance of these fundamental ideas in chemical engineering.

While the escape room incorporates relatively complex chemical engineering concepts, the puzzles are designed with a lower level of difficulty to accommodate a diverse audience. This approach ensures accessibility for a wide range of participants, from high school seniors to college students across various disciplines. The riddles and challenges introduce these core concepts in a simplified manner, allowing participants to engage with the material regardless of their prior knowledge in chemical engineering. This design choice aims to spark interest in chemical engineering principles among younger students while reinforcing basic concepts for those with more advanced studies, creating an inclusive and educational experience for all participants.

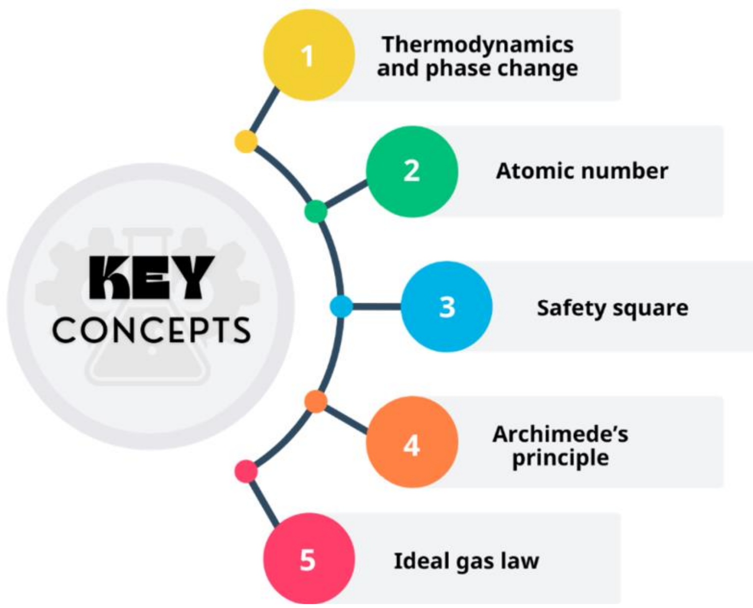


Figure 2. Chemical engineering key concepts involved in the escape room.

Assessment

Quantitative and qualitative methods have their own merits to measure the learning outcomes. The quantitative methods are strong in working towards studying large groups of people and obtaining insights that can assist in obtaining generalized patterns that can then be extended to a bigger group of people. On the other hand, qualitative methods have their strength in obtaining detailed and deep understanding of a certain group of people that might or might not be extended to other groups of people. Incorporating both methods can be useful as the individual strengths of the methods are combined [23]. However, the design of the assessment needs to be chosen based upon the purpose of the research [24]. Our purpose is to understand the effectiveness of escape room as an approach towards learning chemical engineering concepts that can then be extended to a wider range of students, educators and pedagogic experts that are present in the domain of chemical engineering. Aligning with the purpose, we have designed a quantitative scale (SPEER) to measure the effectiveness of escape rooms as a learning method. The scale is designed as an instrument to obtain reports from students, educators present and participating in the ASEE Midwest Section conference.

As highlighted in the literature, the use of escape room as a learning tool is focused towards either making the concepts easy to understand [1],[5] or making the process of learning the concepts easier [6], [8]. This understanding becomes the foundation of our scale. Therefore, the items created in the scale (SPEER) are categorized into content, pedagogy and finally, the overall experience of using escape room as a learning approach. Hence, the organization of SPEER is done in a way that one scale represents each of the three domains and there are subscales composed from the items within the three higher order scales. Our goal was to have fewer than twenty items, a measure as short as possible while still maintaining high reliability [25]. Items are written in a Likert-type format [26], statements catering to content, pedagogy and the overall experience by a five-answer option scale ranging from 5 (strongly agree) to 1 (strongly disagree). Items are only written in one direction and in order to avoid confusion, no item will be reverse scored. Along with the Likert-type format, a space was created to become aware of aspects that might not be covered owing to the objective, quantitative nature of SPEER.

The scale was constructed following validated item-writing rules for attitude scales [27]. Items were composed after going through multiple steps like reading the literature on escape rooms, trying to create the categories as clear as possible, vetting potential items with fellow researcher and wording the items to maintain high comprehensibility and clarity [28]. Attempt was made to create items that are consistent with the literature present on escape room used as a learning approach present to teach chemical engineering concepts effectively [1], [5], [6], [8], [14]. Finally, the group, to whom the scale would be given, additional efforts would be made so that they understand the items and interpret the terminology used in a way consistent with the researcher's intent. The design incorporates the flexibility of five options that would allow for adequate variability to produce reliable results [27]. Finally, the open space present in the scale offers the possibility for the group to add if there were confusions in comprehending and understanding the scale adding to the reliability of SPEER.

Conclusion and Future Work

The comprehensive literature review conducted in this study confirms the multiple benefits of incorporating escape rooms in engineering education. These benefits include enhanced student engagement, improved problem-solving skills, and increased knowledge retention across various engineering disciplines. Our Chemical Engineering Escape Room, developed for the 2024 ASEE Midwest section conference, builds upon these findings while addressing some of the key challenges identified in previous research. By utilizing virtual methods programmed in MATLAB, we have created a more practicable and cost-effective solution that maintains the engaging aspects of traditional escape rooms. The integration of educational brochures as part of the experience further enhances the learning process, providing participants with clear guidance and reinforcing key chemical engineering concepts. This approach allows students to learn fundamental principles in a dynamic and enjoyable manner, potentially increasing their motivation and interest in the subject. The virtual nature of our escape room also offers greater versatility for application across different engineering disciplines, as it simplifies implementation and reduces resource requirements. This adaptability could lead to wider adoption of educational escape rooms in various STEM fields.

As future work, we plan to analyze the data collected from questionnaire administered to escape room participants at the conference. This analysis aims to quantitatively demonstrate the learning outcomes and effectiveness of our approach. The results of this study will provide valuable insights into the impact of virtual escape rooms on students learning in chemical engineering education and may inform future developments in this innovative teaching methodology. Additionally, we intend to explore the potential for adapting our virtual escape room model to other engineering disciplines, further investigating its versatility and effectiveness across different educational contexts.

Acknowledgements

The authors acknowledge the 2024 ASEE Midwest section conference for providing us with the opportunity to implement the educational escape room. In addition, we would like to acknowledge the guidance and advice of Mr. Christian David Vargas Gutierrez on the usage of MATLAB App Designer for the programming and design of the escape room virtual environment.

References

[1] P. Fotaris and T. Mastoras, "Escape rooms for learning: A systematic review," in *Proceedings of the European Conference on Games Based Learning*, 2019, pp. 235-243.

[2] C. Kim, H. Na, N. Zhang, and C. Bai, "Escape rooms for education: A meta-analysis," *International Journal of Instruction,* vol. 17, no. 4, pp. 219-234, 2024.

[3] A. I. V. Vörös and Z. Sárközi, "Physics escape room as an educational tool," in *AIP Conference Proceedings*, 2017, vol. 1916, no. 1: AIP Publishing.

[4] S. Nicholson, "Creating engaging escape rooms for the classroom," *Childhood Education,* vol. 94, no. 1, pp. 44-49, 2018.

[5] C. Borrego, C. Fernández, I. Blanes, and S. Robles, "Room escape at class: Escape games activities to facilitate the motivation and learning in computer science," *JOTSE,* vol. 7, no. 2, pp. 162-171, 2017.

[6] J. Moffett and D. Cassidy, "Building a digital educational escape room using an online design-thinking process," *Online Learning,* vol. 27, no. 2, pp. 223-244, 2023.

[7] A. Neetoo, N. Zary, and Y. Zidoun, "Escape rooms in medical education: deductive analysis of designs, applications and implementations," 2021.

[8] N. Dietrich, "Escape classroom: The leblanc process—An educational “escape game”," *Journal of chemical education,* vol. 95, no. 6, pp. 996-999, 2018.

[9] C. Herrera *et al.*, "Design of an escape room as a gamification activity in chemical engineering. a virtual approach," in *EDULEARN21 Proceedings*, 2021: IATED, pp. 6978-6982.

[10] K. R. Otemaier, P. Zanese, E. Grein, and N. S. Bosso, "Educational escape room for teaching Mathematical Logic in computer courses," *SBC—Proceedings of the SBGames, Recife, Brazil,* pp. 7-10, 2020.
[11] Á. A. Magreñán, C. Jiménez, L. Orcos, and S. Roca, "Teaching calculus in the first year of an engineering degree using a Digital Escape Room in an online scenario," *Computer Applications in Engineering Education,* vol. 31, no. 3, pp. 676-695, 2023.
[12] A. Veldkamp, L. van de Grint, M.-C. P. Knippels, and W. R. van Joolingen, "Escape education: A systematic review on escape rooms in education," *Educational Research Review,* vol. 31, p. 100364, 2020.
[13] L. H. Taraldsen, F. O. Haara, M. S. Lysne, P. R. Jensen, and E. S. Jenssen, "A review on use of escape rooms in education–touching the void," *Education Inquiry,* vol. 13, no. 2, pp. 169-184, 2022.
[14] I. Tejado, E. Pérez, J. Traver, C. Nuevo-Gallardo, P. Rodríguez, and B. Vinagre, "Design of an escape room to support learning of industrial process control in engineering degrees," in *INTED2021 Proceedings*, 2021: IATED, pp. 2171-2180.
[15] D. de la Flor, J. A. Calles, J. J. Espada, and R. Rodríguez, "Application of escape lab-room to heat transfer evaluation for chemical engineers," *Education for chemical engineers,* vol. 33, pp. 9-16, 2020.
[16] L. N. Heckelman and E. K. Bucholz, "Designing a MATLAB-based escape room," in *2020 ASEE Virtual Annual Conference Content Access*, 2020.
[17] A. Makri, D. Vlachopoulos, and R. A. Martina, "Digital escape rooms as innovative pedagogical tools in education: A systematic literature review," *Sustainability,* vol. 13, no. 8, p. 4587, 2021.
[18] S. López-Pernas, A. Gordillo, E. Barra, and J. Quemada, "Examining the use of an educational escape room for teaching programming in a higher education setting," *IEEE Access,* vol. 7, pp. 31723-31737, 2019.
[19] M. Hermanns, B. Deal, S. Hillhouse, J. B. Opella, C. Faigle, and R. H. Campbell IV, "Using an" escape room" toolbox approach to enhance Pharmacology Education," 2017.
[20] H. N. Eukel, J. E. Frenzel, and D. Cernusca, "Educational gaming for pharmacy students–design and evaluation of a diabetes-themed escape room," *American journal of pharmaceutical education,* vol. 81, no. 7, pp. 62-65, 2017.
[21] J. L. Gómez-Urquiza, J. Gómez-Salgado, L. Albendín-García, M. Correa-Rodríguez, E. González-Jiménez, and G. A. Cañadas-De la Fuente, "The impact on nursing students' opinions and motivation of using a “Nursing Escape Room” as a teaching game: A descriptive study," *Nurse education today,* vol. 72, pp. 73-76, 2019.
[22] S. Clarke, D. Peel, S. Arnab, L. Morini, and O. Wood, "EscapED: A framework for creating educational escape rooms and interactive games to for higher/further education," *International Journal of Serious Games,* vol. 4, no. 3, pp. 73-86, 2017.
[23] T. R. Hinkin, "Scale development principles and practices," *Research in organizations: Foundations and methods of inquiry,* vol. 1, pp. 161-179, 2005.
[24] D. C. Miller and N. J. Salkind, *Handbook of research design and social measurement*. Sage, 2002.
[25] J. Raubenheimer, "An item selection procedure to maximize scale reliability and validity," *SA Journal of Industrial Psychology,* vol. 30, no. 4, pp. 59-64, 2004.
[26] A. Joshi, S. Kale, S. Chandel, and D. K. Pal, "Likert scale: Explored and explained," *British journal of applied science & technology,* vol. 7, no. 4, pp. 396-403, 2015.

[27] P. B. Sheatsley, "Questionnaire construction and item writing," *Handbook of survey research,* vol. 4, no. 1, pp. 195-230, 1983.
[28] S. Carpenter, "Ten steps in scale development and reporting: A guide for researchers," *Communication methods and measures,* vol. 12, no. 1, pp. 25-44, 2018.

Alejandra Torres Velasco

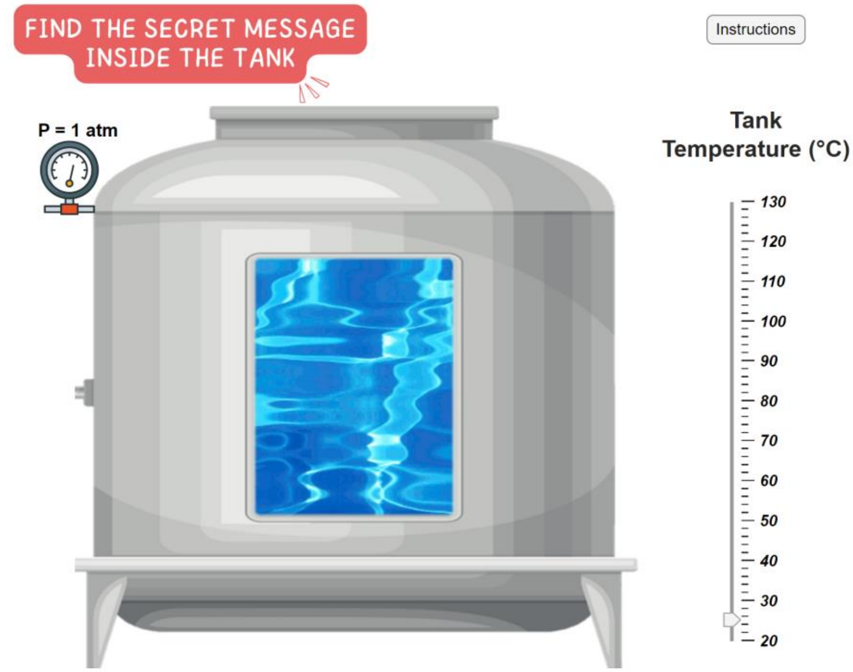
Ms. Torres is a Ph.D. student in Chemical and Petroleum Engineering at the University of Kansas. Currently, she is a graduate research and teaching assistant in the Chemical and Petroleum Engineering Department at KU. She is deeply passionate about advancing the field of chemical engineering education. Her commitment and excellence in teaching were recognized with the Outstanding Graduate Teaching Assistant Award in the spring of 2024.

Abhishek Juneja

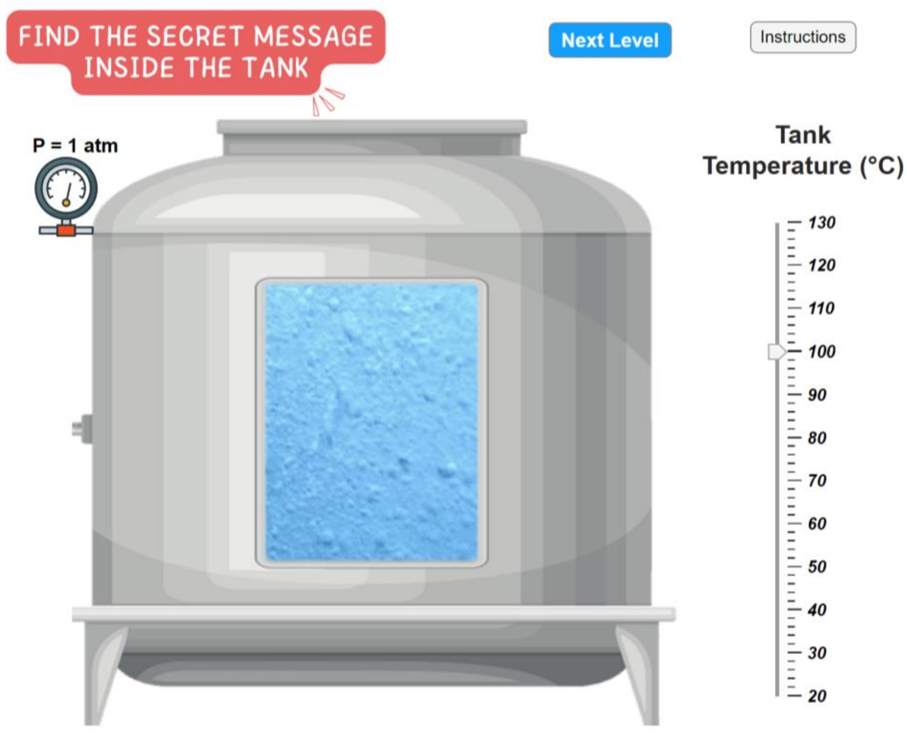
Mr. Juneja is a Ph.D. student in Educational Psychology at the University of Kansas. Currently, he is a graduate research and teaching assistant with Achievement and Assessment Institute (AAI) at KU. He is passionate about combining principles of education and psychology to help students, across different fields and ethnicities, to apply the concepts learned in an experiential way in the real world.

Appendix I: Graphical interface of the escape room applications.

A)



B)



C)

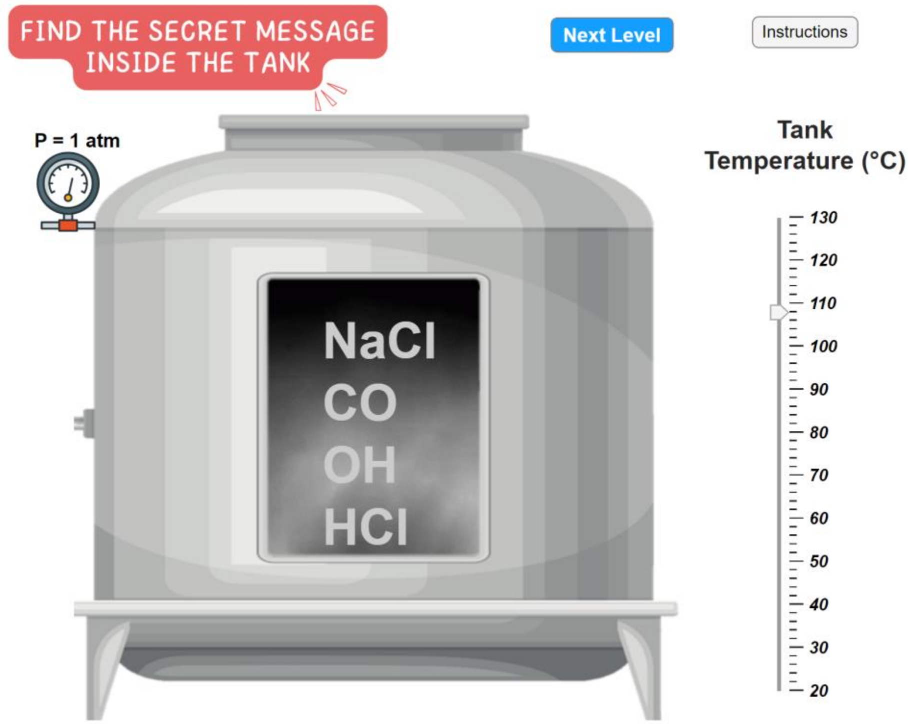
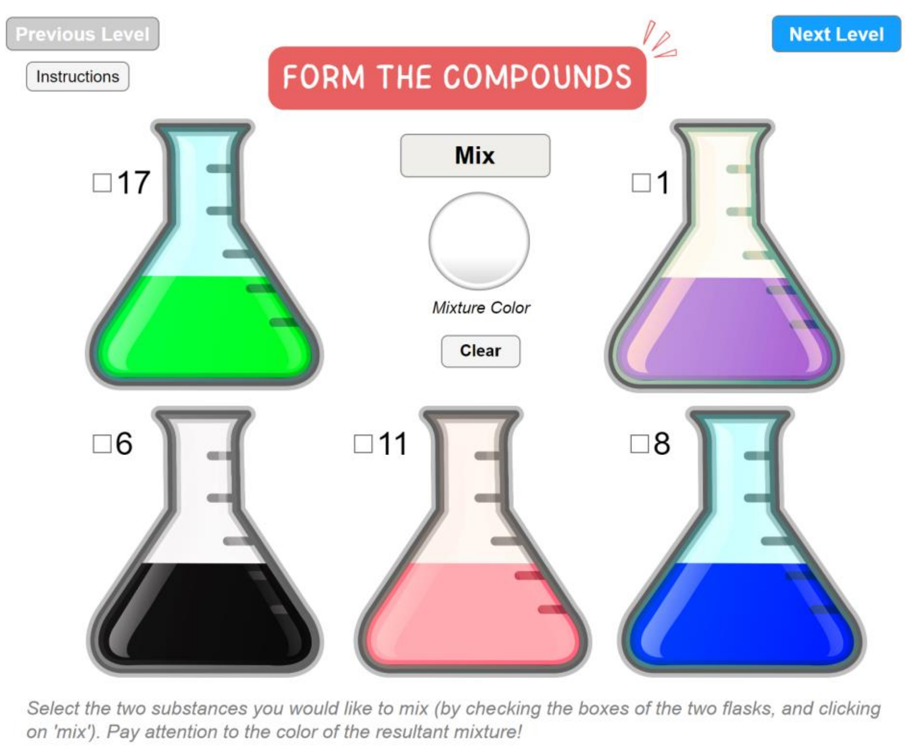


Figure 3. First section of the escape room: Finding the secret chemical compounds. A) Starting application. B) Setting the temperature conditions at the ebullition point of water (100°C). C) Finding the secret message.

A)



B)

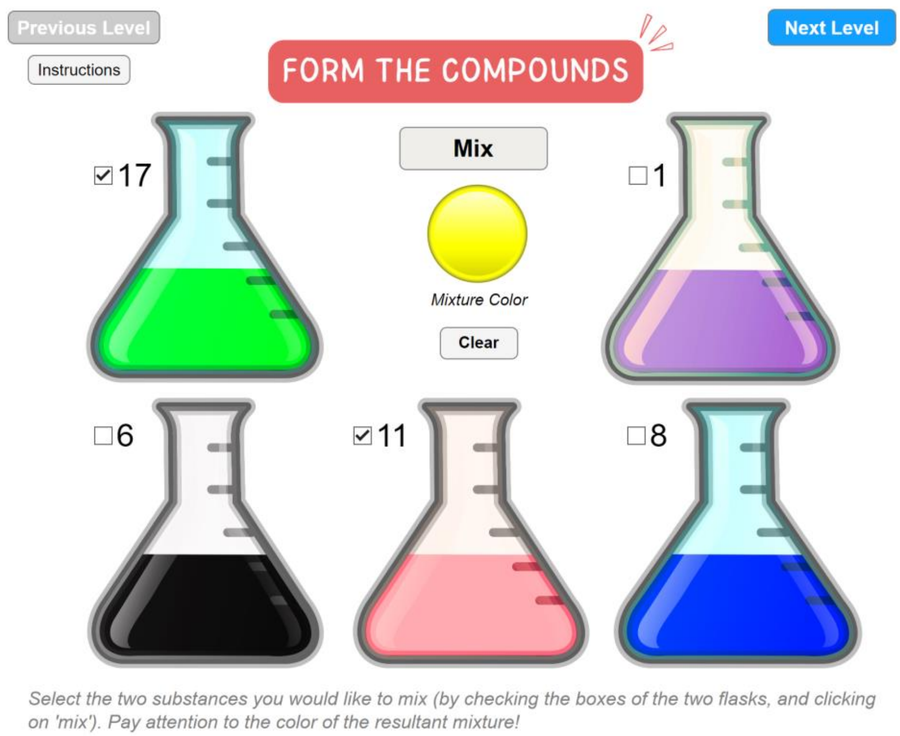
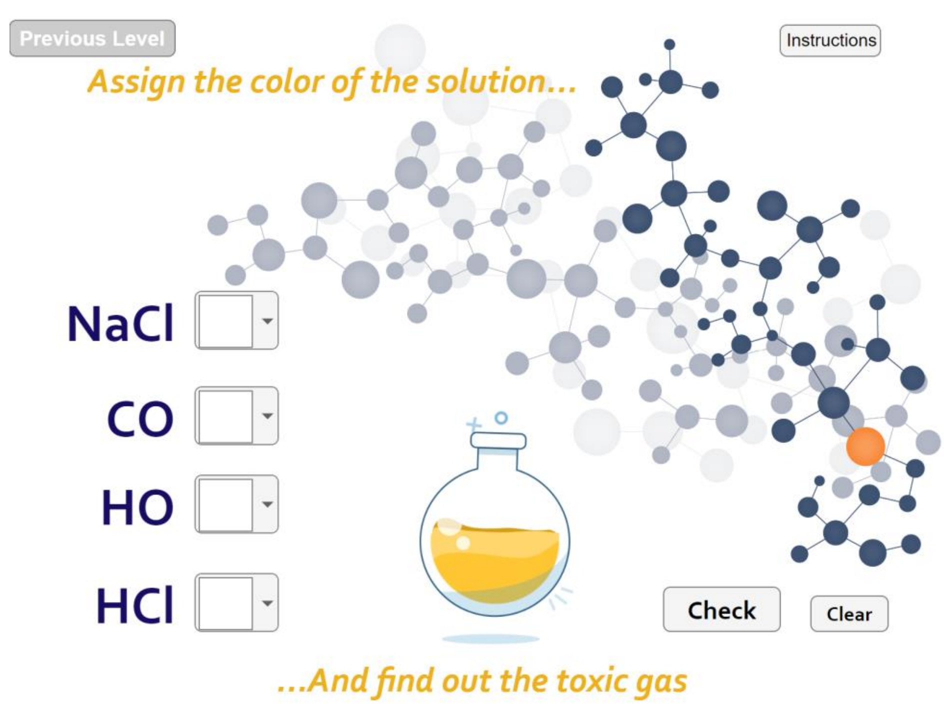
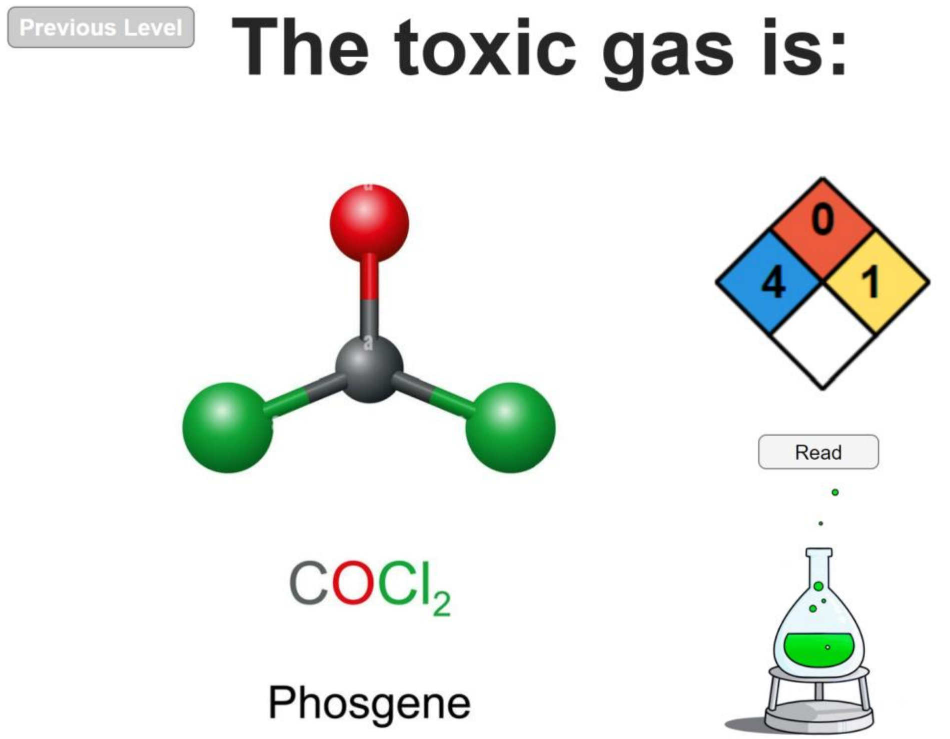


Figure 4. Second section of the escape room: Forming compounds. A) Starting application. B) Combining the two elements (according to their atomic numbers) to form the compounds and get the respective color key codes.

A)



B)



C)

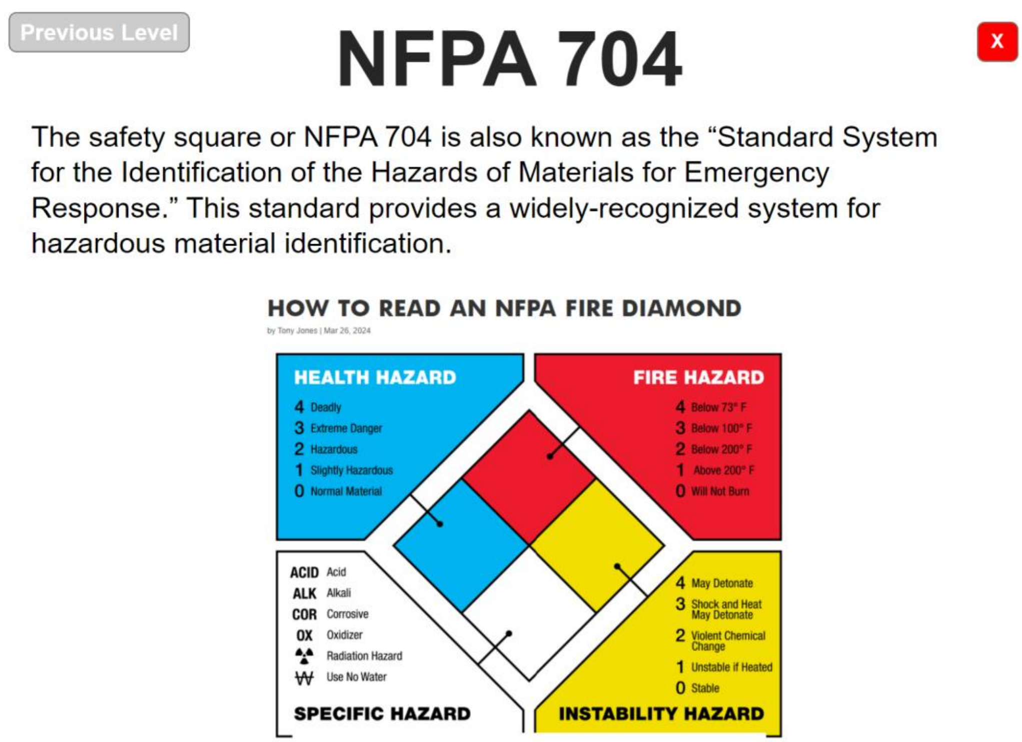
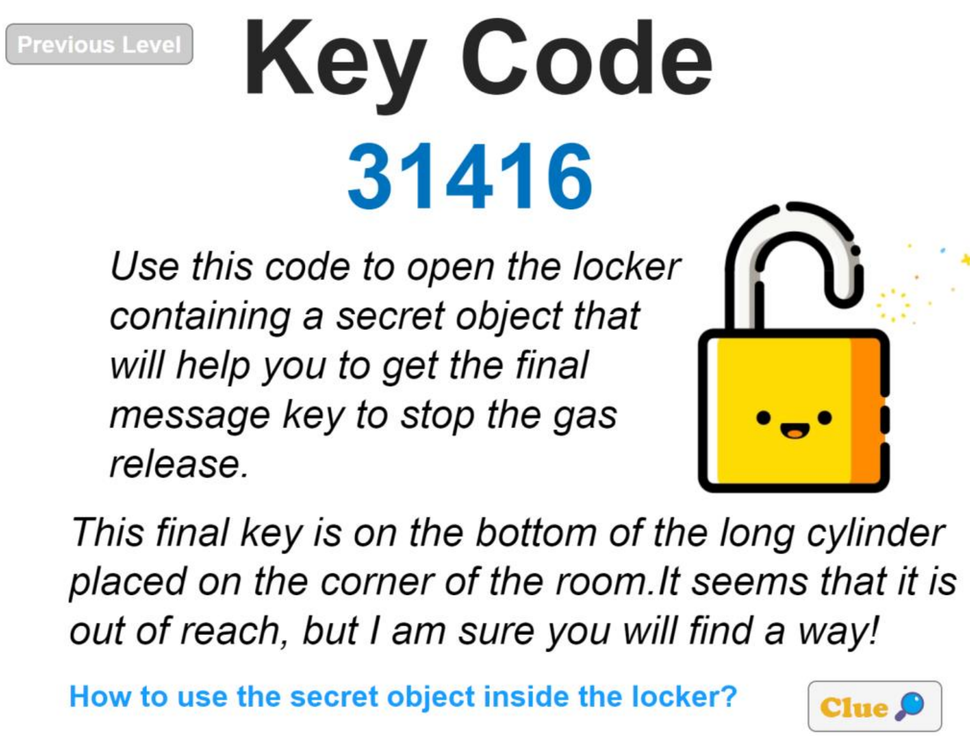


Figure 5. Third section of the escape room: Identifying the toxic chemical. A) Starting application. B) Identification of the toxic gas after introducing the correct color code for each compound. C) Instructions window.

A)


Previous Level
What is the toxic gas?
TOXIC GAS
Compound Name
Health Hazard
Clear
Check

B)


Previous Level
Key Code
31416
Use this code to open the locker containing a secret object that will help you to get the final message key to stop the gas release.
This final key is on the bottom of the long cylinder placed on the corner of the room.It seems that it is out of reach, but I am sure you will find a way!
How to use the secret object inside the locker?
Clue

C)

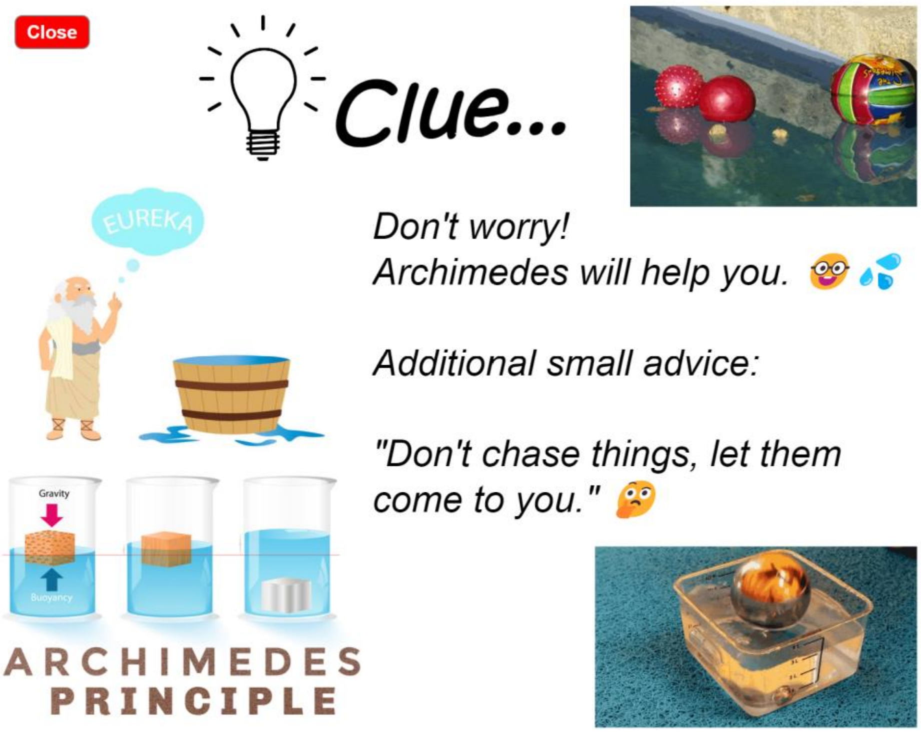
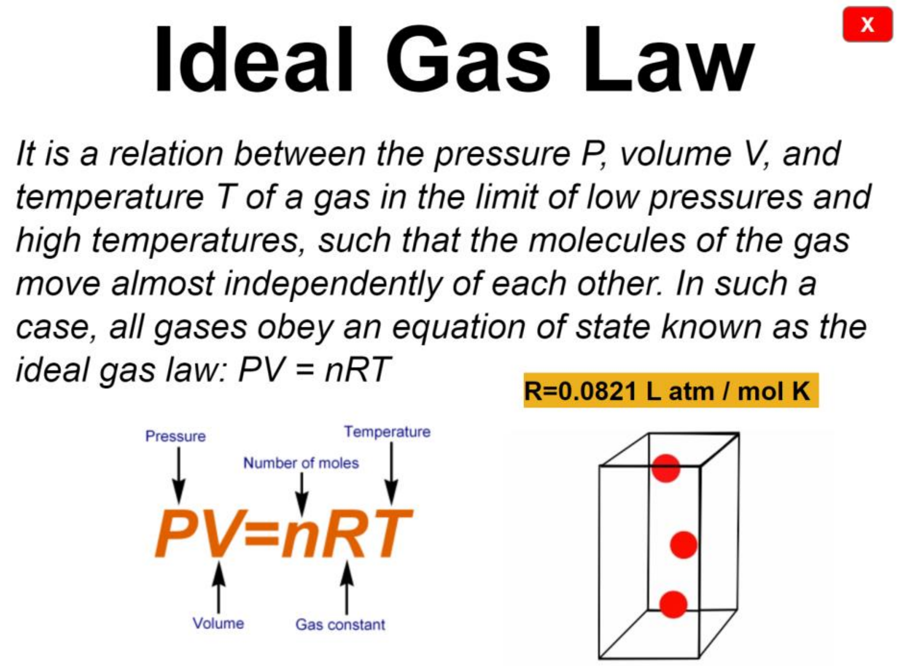


Figure 6. Fourth section of the escape room: Locating the key code to stop the release. A) Starting application. B) Getting the numerical key code for the next section after introducing the name of the toxic compound. C) Clue window.

A)

B)



C)

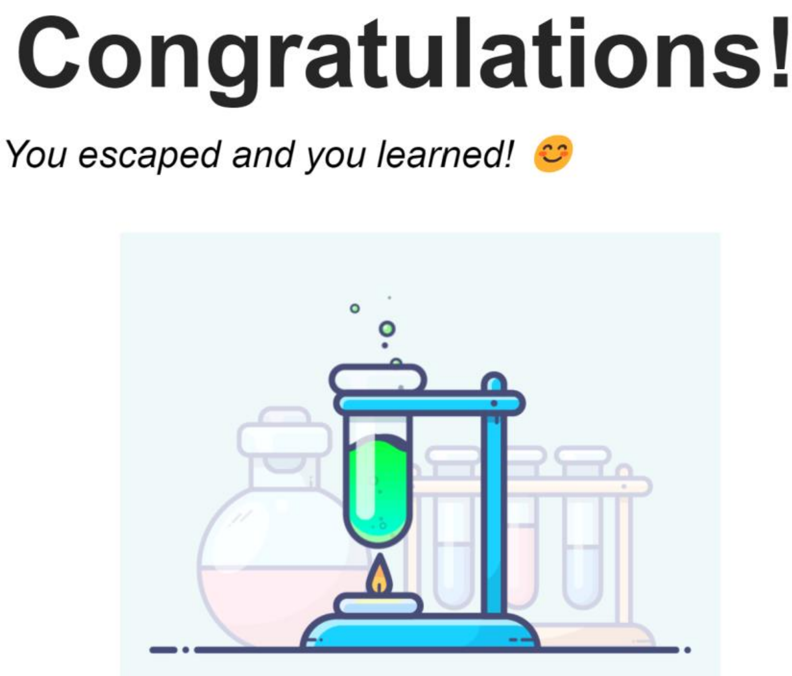


Figure 7. Fifth section of the escape room: Stopping the release. A) Starting application. B) Clue window. C) Escape room completion message after correctly solving the problem applying the key concept (ideal gas law).

Appendix II: Escape room brochures.

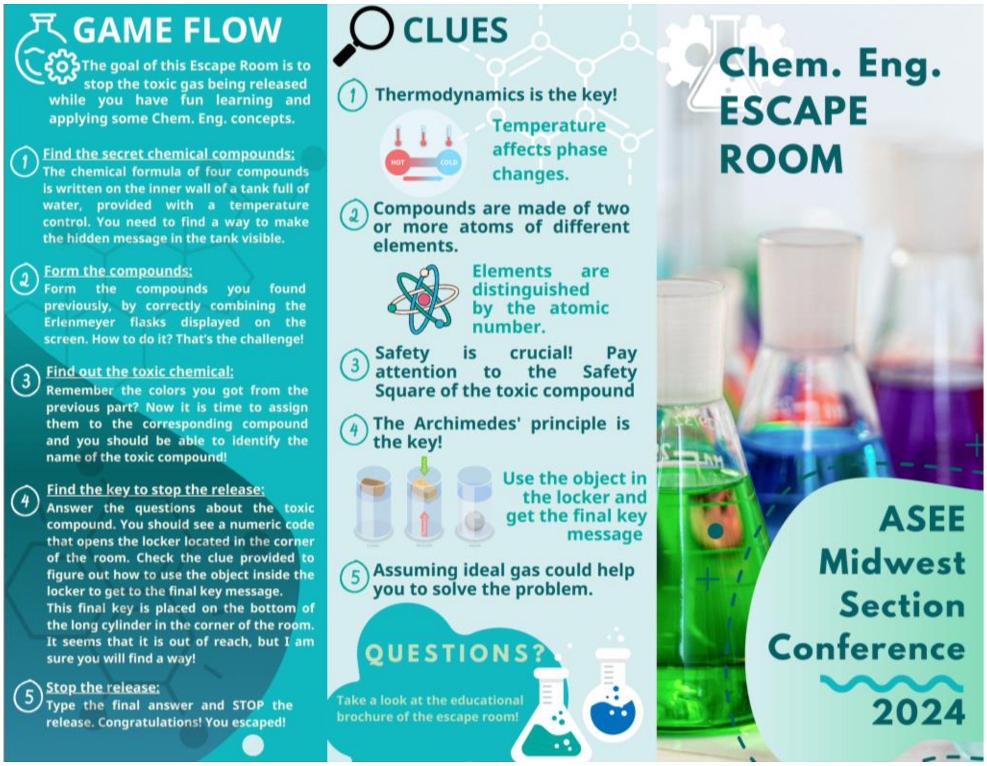


Figure 8. Game flow brochure.

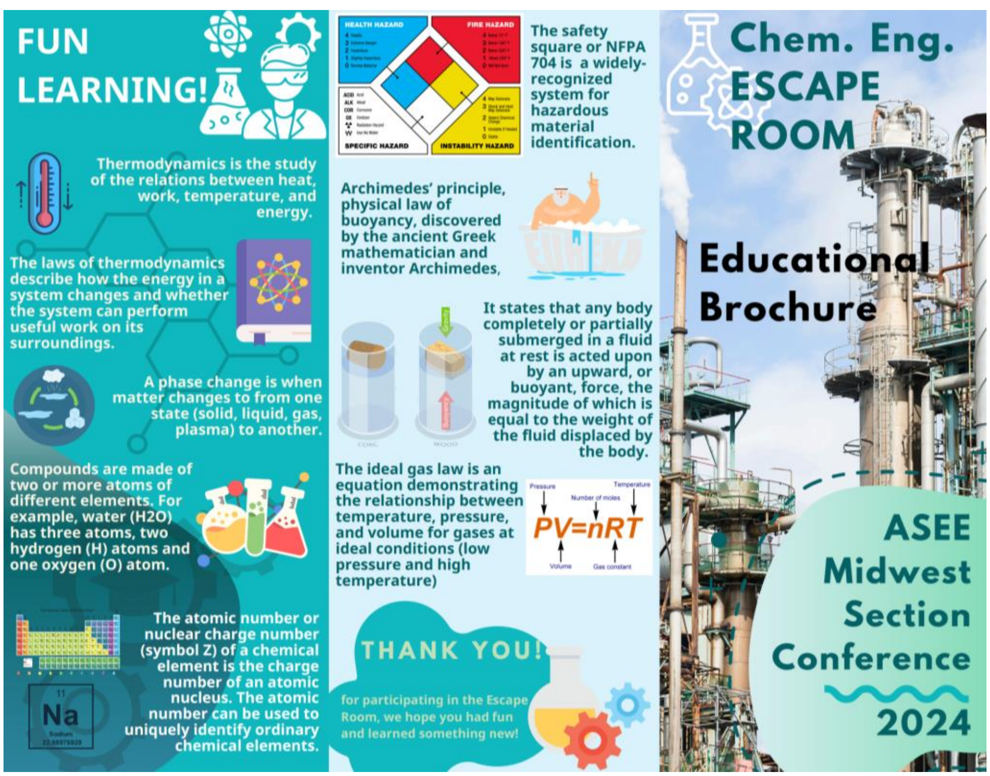


Figure 9. Educational brochure.

Appendix III: Questionnaire.

Scale for Pedagogic Experience of the Escape Rooms (SPEER):

A. Content	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
1. I learned more of atomic number and chemical element identification because of escape room.					
2. The escape room covered the concept of phase change well.					
3. Safety square become easy to understand because of escape room.					
4. I know more of Archimedes' Principle because of escape room.					
5. The escape room covered the concept Ideal Gas Law well.					
6. The escape room motivated me further to learn about other chemical engineering concepts.					
7. The escape room allowed me to apply theoretical knowledge in a more practical way.					
B. Pedagogy	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
1. The activities of the escape room were engaging and appropriately challenging.					
2. The educational tools (like brochure, clues etc.) and colourful graphics were helpful in solving puzzles					
3. The sequence of activities was appropriately designed to reach the end of the escape room.					
4. The time constraints added to the thrill and excitement of the escape room.					
C. Overall Experience	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
1. The overall experience of escape room helped me					

develop important skills (like communication, teamwork, critical thinking etc.)					
2. I found the experience participative and interactive.					
3. I would recommend escape room as an educational tool to other students.					
4. I would like to participate in another educational escape room in the future.					

Feedback, Suggestions and Comments