

Supporting First-Year Chemistry Undergraduates in Data Analysis through a Gamified Excel Escape Room

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ABSTRACT: Excel proficiency is a critical tool in undergraduate chemistry education, yet many students lack confidence in performing essential data handling and analysis tasks. To address student apprehension and encourage engagement with the software, this work reports the development of an Excel-based escape room. The activity is built entirely within the Excel environment, utilizing conditional formatting and password-protected sheets to create a self-contained, interactive learning experience without the need for external software or funding. The activity was trialed with a cohort of first-year undergraduate chemistry students. Participants reported positive shifts in their perception of Excel, noting increased confidence and a greater willingness to apply the software for complex tasks following the intervention. While direct skill acquisition requires longitudinal study, survey data suggests that gamifying the Excel environment can effectively lower the perceived barrier to entry for hesitant students. By embedding skill development within an exploratory framework, this model offers a scalable, adaptable tool for introducing digital literacy in the chemical sciences.

KEYWORDS: *First-Year Undergraduate, Analytical Chemistry, Computer-Based Learning, Laboratory Computing, Excel, Gamified Learning, Escape Room, Laboratory Computing/Interfacing*



INTRODUCTION

Spreadsheet usage is a fundamental skill in science careers, particularly for data handling and analysis.¹ Compared to manual calculations, spreadsheets offer numerous advantages: they maintain high precision across calculations, enable error detection in multistep operations, and allow for rapid recalculations by modifying input values.^{2,3} In chemistry education and research, this efficiency is especially beneficial for tasks like sequential dilutions and molarity calculations, where researchers perform the same complex computations as part of daily laboratory operations.⁴

Beyond simple calculations, spreadsheet proficiency is a powerful research tool. Many chemistry disciplines rely on Excel for statistical analysis and data visualization, making it an essential component of laboratory coursework.⁵ Excel also has significant value as a pedagogical tool, allowing for accessible visualization of complex concepts such as peak integration⁶ or iterative computational methods,⁷ which offers clearer learning opportunities relative to the “black-box” nature of automated commercial software.⁸ Additionally, Excel skills are highly transferrable to a wide range of careers,⁹ reinforcing the need for its integration into the chemistry curriculum.

In the rapidly evolving digital landscape, spreadsheet handling is likely to remain relevant alongside artificial intelligence (AI). While AI is also a powerful tool for data visualization,¹⁰ Excel’s ubiquity and ease-of-use make it ideal for small to medium data tasks. Excel proficiency will likely remain important as AI becomes more deeply embedded, when human oversight will

become a vital skill to monitor the validity of AI-driven analytics.¹¹

The Excel Skills Gap

Despite its importance, few students arrive in higher education proficient in Excel.^{2,12} Many students in teaching laboratories rely on pen-and-paper calculations, leading to errors that are difficult to trace, causing frustration and discouragement. In first-year undergraduate programs, these struggles can negatively impact students’ confidence, particularly as they adapt to the laboratory environment.¹³ A lack of spreadsheet proficiency can slow students down in time-constrained practical sessions, potentially leading them to misinterpret their struggles as a deficiency in chemistry knowledge or ability, rather than a technological skills gap.¹⁴

The origin of this gap is multifaceted. While spreadsheet usage is included in UK secondary education computer science curricula^{15–19} it is often not reinforced in science courses. As a result, students may not recognize its relevance outside of computing classes, leading to poor skills retention.^{20,21} This lack

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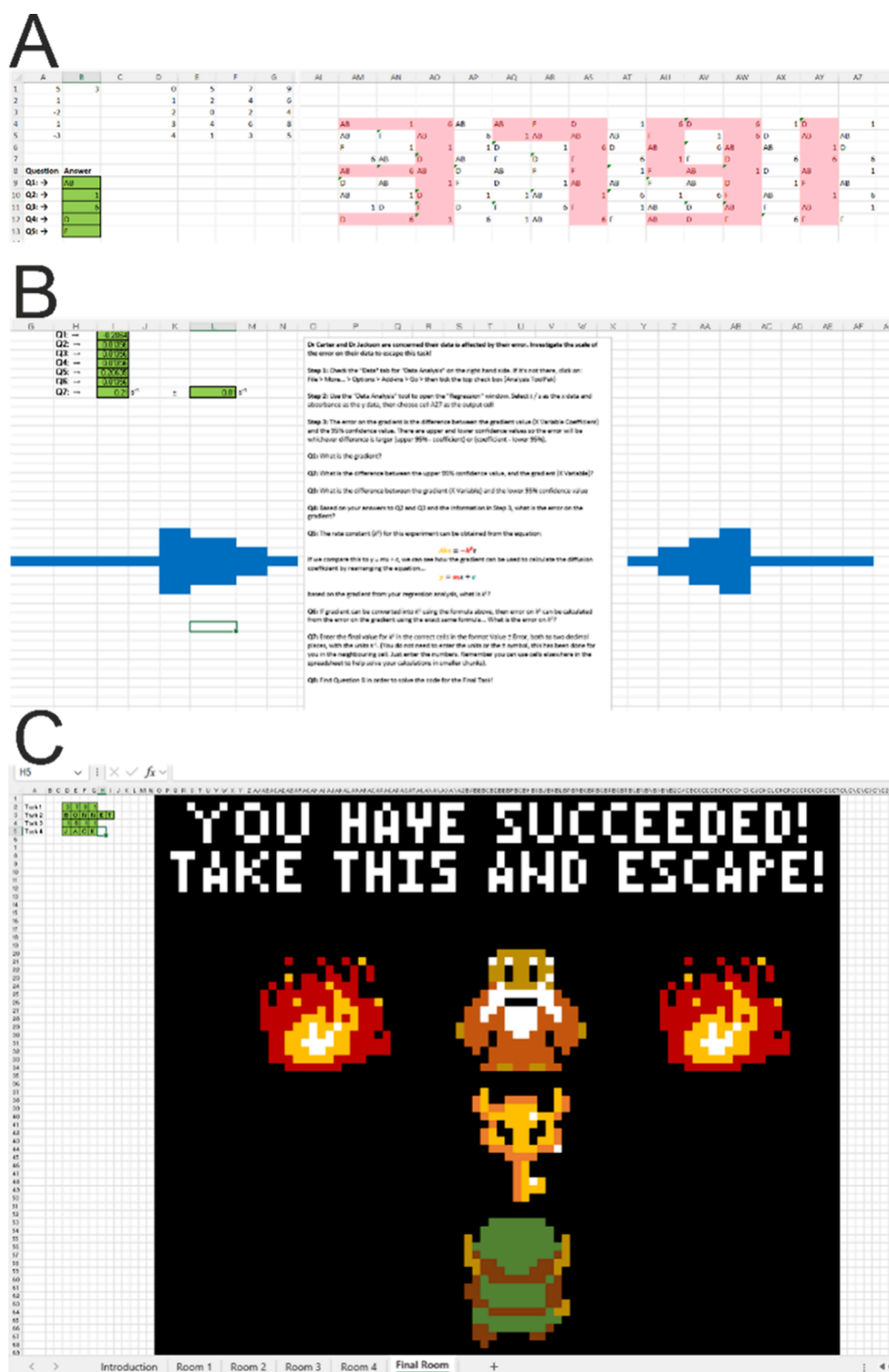


Figure 1. Screenshots from the Excel escape room demonstrating the various roles of conditional formatting. (A) Conditional formatting has been used to confirm correct answers (green cells) and reveal a code (red cells). (B) Conditional formatting reveals blue arrows pointing to a hidden bonus question. (C) Final splash screen that students see on completion of the escape room. Resizing the cells to squares allows construction of pixel art for a more engaging and rewarding completion screen.

of reinforcement may result in a skills regression prior to starting higher education.²²

Furthermore, educators cannot assume universal digital literacy.²³ Overreliance on mobile apps, gaps in teacher training, and socioeconomic factors can limit students' exposure to traditional computing skills.^{24,25} Therefore, educators must assume varying levels of prior experience and provide learning

opportunities for spreadsheet usage in a way that is accessible, engaging and confidence-building.

Gamified Learning as an Instructional Strategy

Standard training programs for digital skills such as Excel are effective, but often require a sizable amount of staff and student time that curricula may not be able to accommodate.²⁶ Additionally, standalone training can lead to disengagement²⁷

and may only offer moderate improvements in proficiency.²⁸ If students struggle to acquire spreadsheet proficiency early on, they may develop negative perceptions of their ability, an issue particularly prevalent among first-generation students.²⁹ Thus, Excel training should be introduced in a supportive and engaging learning environment.

Gamified learning offers a solution by embedding skill development within interactive, problem-based challenges, enhancing engagement, motivation, and retention.^{30–33} Challenges suitable to a player's skill level are a common motivator in all games, and are a fundamental component of the flow state that leads to a feeling of immersion in the experience.³⁴ Another is the provision of timely feedback related to clear goals, which aims to promote autonomy and increase effort and attention to a task.³⁵

Student responses to gamified learning tend to be positive, with students reporting increased enthusiasm, useful feedback, and promoting goal setting.³² Various approaches, from card games³⁶ to immersive virtual reality experiences³⁷ have been successfully used to teach scientific concepts³⁸ and software skills, including Excel.³⁹

Escape Rooms for Gamified Learning

Among gamified formats, escape rooms have emerged as effective tools for learning.⁴⁰ Vorderbermeier et al.⁴¹ identify nine prominent theoretical models related to escape rooms, many of which underpin this study. These include the use of narrative, challenge-based progression, and immediate feedback, all of which contribute to the immersive and educational experience.

Escape rooms are grounded Problem-based Learning, as students tackle real-world, discipline-specific challenges to solve the room puzzles.⁴² Flow theory underpins the engagement goals of the escape room, where tasks are designed to balance difficulty with student skill levels to facilitate optimal immersion and motivation.³⁴ Designers may also consider Self-Determination Theory,⁴³ where escape room puzzles are designed to be solved independently to promote autonomous learning. Similar benefits have been observed in both in-person and virtual escape rooms, although in-person rooms do tend to promote students' fun and engagement.⁴⁴

Unfortunately, many gamified learning tools require significant financial and time investments.⁴⁵ High production costs, reliance on specialized software and limited flexibility can make these methods impractical for many institutions.^{46,47} Additionally, some gamified experiences, especially those with elaborate interfaces, may inadvertently distract from core learning objectives.⁴⁸ Designers for gamified learning approaches must therefore balance the enjoyable nature of the escape room with the desired learning outcomes.⁴⁹

To address these challenges, this work presents an Excel-based digital escape room as a cost-effective and immersive method for introducing spreadsheet skills. Unlike traditional gamified learning platforms, our approach embeds the learning experience directly within Excel. This enhances software familiarity, while requiring no additional resources or costs beyond staff design time. It is highly adaptable, allowing instructors to modify activities based on course needs and student feedback. The same concept could also be applied to free-to-use software such as Google Docs or LibreOffice Calc for institutions or individuals without access to Microsoft packages. This report details the design and implementation of the escape

room, and evaluates student perceptions if its effectiveness in improving student confidence and willingness to use Excel.

■ ESCAPE ROOM DESIGN AND IMPLEMENTATION

The Excel escape room utilizes standard, built-in Excel features to replicate the “locks” and “keys” of a traditional escape room. This ensures the tool is free to develop (excluding instructor time) and requires no software installation beyond Microsoft Office (or suitable free alternative).

Technical Framework

The design relies on two Excel features. The first is “Conditional Formatting”, which dynamically alters cell properties (e.g., font colour, background, borders) based on content. In the escape room context, conditional formatting is used to confirm correct answers by turning cells green. This immediate feedback aims to promote learning and confidence and facilitate gamified flow.

The same method can reveal hidden text by changing font color from white to black, thereby displaying a secret code. A more engaging approach involves using conditional formatting to fill cells with color, effectively painting images or patterns on the Excel grid. The password can then be embedded as a word or code within the design, or students may need to interpret a visual clue to deduce the password. Figure 1 illustrates how conditional formatting offers multiple functionalities within the Excel escape room.

While conditional formatting technically allows students to uncover passwords by examining formatting rules, this was deemed an acceptable trade-off. Students capable of identifying these conditions already demonstrate a level of Excel proficiency that suggests they do not require the full learning experience. Therefore, rather than enforcing additional restrictions, the design prioritizes engagement and accessibility.

The second key feature is “Sheet Protection”, which restricts access to specific sheets (or “rooms”) within an Excel workbook. Users can view the content of a protected sheet but cannot modify it until they enter the correct password. The Excel escape room presents students with a structured series of Excel learning challenges. Upon completing each challenge, conditional formatting reveals a password granting access to the next “room”.

Pedagogical Structure

The Excel escape room is grounded in complementary learning theories that collectively inform the design and expected outcomes.^{43,50} The escape room is structured progressively: early rooms introduce fundamental Excel skills and syntax, then later rooms build upon these foundations with concepts such as data plotting and linear regression analysis. This scaffolded approach aims to reinforce prior knowledge while introducing new skills, aiming to promote a progressive mastery of Excel.⁵¹

The design aims to be self-contained, fostering independent learning by exploration. Given that many students are accustomed to app-based technology with simplified interfaces, developing the ability to navigate Excel's submenus is a key learning outcome. Immediate feedback is provided both for the completion of major challenges and minor steps along the way using conditional formatting.⁵² This provides an autonomy-supportive design, encouraging self-directed learning and intrinsic motivation through the gamified challenge.⁵³

To enhance engagement, all tasks are framed within the context of real-world chemistry challenges,⁵⁴ reflecting the principles of Problem-Based Learning.⁴² Skills are chosen based on their relevance to undergraduate chemistry practical sessions,

Table 1. Summary of Skills Covered in the Excel Escape Room, Organized by “Room” Number^a

Room number	Skills	Context
1	Copy-pasting values with relevant syntax (e.g., \$\$ to fix cell references). Click and drag for copying and extending sequences. Basic calculations between cells	Students are given a table of five values. By copying, pasting and calculating values into new cells they are able to reveal a password.
2	Graph plotting and formatting, including axis labels, trendlines etc.	Students are given current versus time data from a model experiment that they must plot correctly so that the data points to a puzzle solution. Previous skills in calculations and extending sequences are revisited to organize the data before plotting.
3	Using Excel built-in functions	Students have to create new data sets using Excel functions such as SQRT (square root) or AVERAGE (mean average). Previous skills in graph plotting and cell referencing are built on to solve the puzzle.
4	Linear regression and error propagation	Students perform a linear regression and error analysis on a model data set. Calculations and cell referencing are touched on lightly as regression is a newly introduced concept.

^aFollow on rooms touch on previously mentioned skills, but with greatly reduced scaffolding. See the [supplementary notes](#) for a more detailed overview of design concepts.

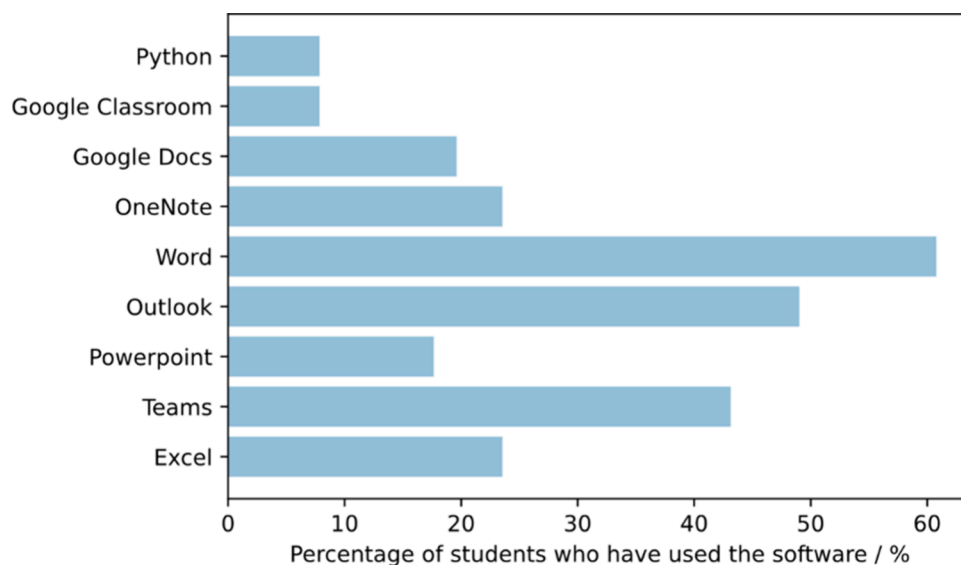


Figure 2. Percentage of students who reported regular use of different software applications prior to enrolling in a university chemistry course ($n = 51$).

and real-world experimental data sets are used, allowing students to solve authentic scientific problems while simultaneously developing Excel proficiency. Hidden pop culture references are also embedded to foster student interest.

Although here focusing on chemistry skills, the design is highly adaptable. The same Excel escape room concept could readily be applied to other disciplines or student cohorts by tailoring the challenges to their required skillsets. A summary of the skills covered in this escape room is provided in [Table 1](#), with a more detailed overview given in the [Supporting Information](#).

EVALUATION OF THE STUDENT EXPERIENCE

Participants and Setting

The activity was implemented during a scheduled four-hour laboratory session with fifty-one first-year undergraduate chemistry students at the University of Southampton. Participation in the activity was mandatory, but the submission of the evaluation survey was voluntary and anonymous. No unexpected hazards were encountered.

Survey Instrument

A custom survey was developed to evaluate student perceptions, aligning with constructs of self-confidence, perceived challenge, and digital literacy.⁵⁵ The 10-point Likert-scale questions assessed students' confidence and willingness to use Excel. To

measure perceived self-confidence with Excel use, categorical questions (scored 0–3) asked students to rate the level of help they would need for specific tasks. Additional items evaluated students' perceptions of the escape room's educational value, enjoyment, and challenge level, including a specific question on the competitive element to assess its motivational impact.

The same questions were asked before and after completing the escape room challenge. Anonymity was maintained by including the “before” and “after” question sets on either side of the same piece of paper distributed to students. Students returned the completed two-sided questionnaire to a bin at the end of the session. Pre- and postintervention differences were analyzed using a Wilcoxon signed-rank test, as collected data did not display a clear normality on visual inspection of histograms.

The internal consistency of the questionnaire was validated by calculating Cronbach's alpha ($\alpha = 0.86$) for the four questions that investigate perceived self-confidence and willingness to use Excel.⁵⁶ All questions asked and Likert scale responses are available in the [Supporting Information](#).

RESULTS AND DISCUSSION

Student Engagement and Completion

The escape room took place during a four-hour timetabled session. Most students (48/51) were able to complete the escape room independently within the session, suggesting the

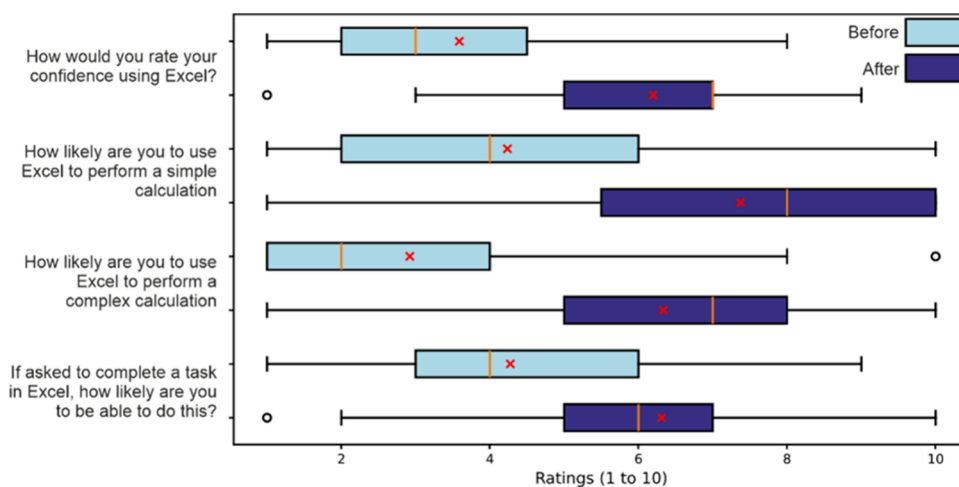


Figure 3. Box-and-whisker plot of student Likert-scale responses to four questions assessing confidence in using Excel before (light blue) and after (dark blue) completing the escape room. The orange bar indicates the median response, hollow circles are outlier responses, and the red x indicates the mean. A rating of 10 indicates high confidence, while 1 indicates no confidence ($n = 51$).

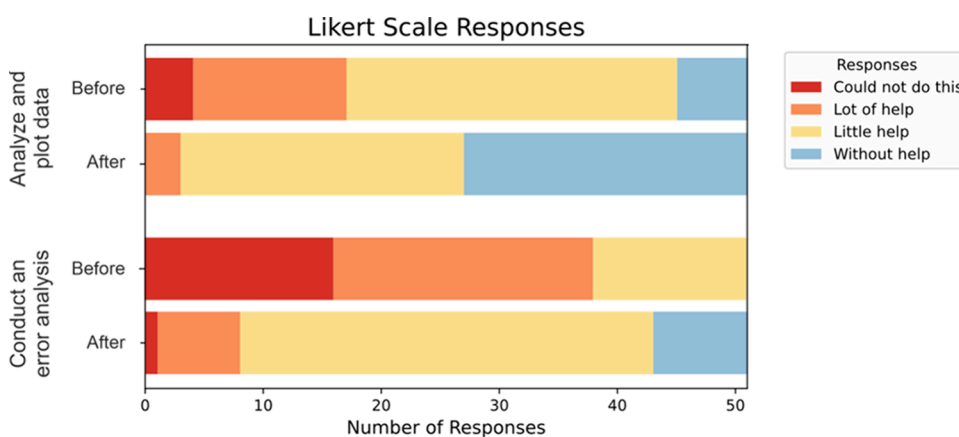


Figure 4. Student responses to the question, “How much help would you need to analyse and plot data or conduct an error analysis in Excel?” before and after the escape room activity. Following the escape room, the proportion of students who believed they could complete the task independently increased, compared to pre-escape room responses ($n = 51$).

design is suitable for promoting autonomous learning. Although hints were available (incorporating a 30 min “time penalty” to mimic traditional escape room game mechanics), no students opted to use them, suggesting a strong motivation to solve problems independently.

Prior to the session, fewer than 25% of student reported regular use of Excel (Figure 2). This lack of exposure correlated with a low baseline confidence (mean 3/10) compared to those who reported they used Excel more regularly (mean 5.5/10). Students expressed hesitancy even toward performing simple calculations, with an even greater reluctance to use Excel for more complex tasks (Figure 3). This trend suggests that rather than being perceived as a tool to facilitate calculations, Excel itself was seen as an obstacle to problem-solving.

Impact on Perceived Self-Confidence and Willingness to Use Excel

Following completion of the escape room, students reported significant improvements in perceived confidence (mean increase = 2.6/10, $p < 0.01$), willingness to use Excel for both simple (mean increase = 3.1/10, $p < 0.01$) and complex calculations (mean increase = 3.4/10, $p < 0.01$), and belief in their ability to navigate new Excel tasks through independent exploration (mean increase = 2.4/10, $p < 0.01$).

Additionally, students were asked to assess the level of assistance they believed they would require for two specific tasks (Figure 4). Results showed a significant reduction in perceived need for assistance on both data analysis and graph plotting (mean increase = 1.0/4, $p < 0.01$) and complex error analysis (mean increase = 0.7/4, $p < 0.01$).

These results suggest that the gamified format helped lower the perceived “barrier to entry” for these students. By providing immediate feedback via conditional formatting, the escape room allowed students to self-correct errors without instructor intervention, fostering the improved self-confidence reported in the survey.

Competition and Enjoyment

A competitive element was incorporated into the design with the aim of further enhancing engagement. Students were encouraged to record their completion times, as is done in a traditional escape room. Student feedback on this aspect was mixed (Figure 5). While overall enjoyment and perceived usefulness were rated highly, the competitive element received lower scores. This suggests that, although competition was intended as an engagement mechanism, the associated time pressure may have contributed to stress rather than enhancing

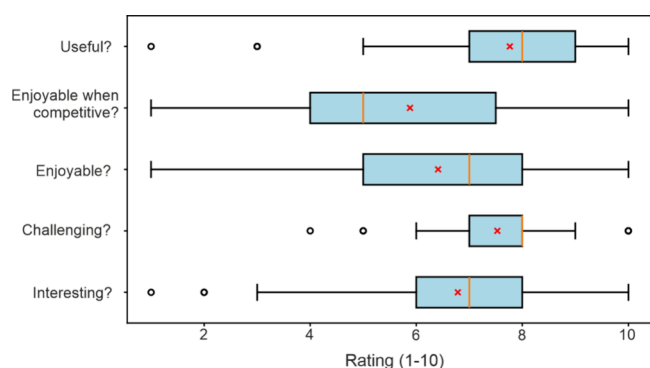


Figure 5. Likert-scale responses evaluating the escape room experience. The orange bar indicates the median response, hollow circles are outlier responses, and the red x indicates the mean. Questions assessed (from top to bottom): perceived usefulness, enjoyment of the competitive element, overall enjoyment, level of challenge, and interest in the activity ($n = 51$).

engagement for some students. This interpretation is supported by the relatively high scores for perceived challenge level.

This reflects broader findings in the literature, where competition in gamified learning is recognized as a double-edged sword.⁵⁷ One of the key challenges is that the precise mechanism by which competition impacts learning is not well-known.^{30,58} Competition has potential as a motivator by enhancing engagement, focus, and goal orientation.^{59,60} However, competition may also increase student anxiety, particularly when students perform poorly relative to their peers.^{61,62} Some works suggest that competitive elements may decrease intrinsic motivation, as students become more focused on competitive rank than skill mastery.⁶³

Competition may be effective as a motivator by design, but its impact is context dependent, and must therefore be carefully managed to avoid demotivation.^{64,65} Cao et al. found improved performance, emotional response and motivation in gamified learning when students were allowed autonomy in choosing their level of competition.⁶⁶ Students could therefore benefit from competitive elements in gamification if they choose, while also respecting the diversity of learners.

Limitations

Efforts were made to minimize desirability bias in responses by providing individual and anonymous questionnaires. Students were not told that the escape room was designed by the instructor to remove implied pressured to provide positive scores. Despite reasonable efforts, desirability bias in the data cannot be entirely ruled out.

Additionally, this study evaluates student perceptions immediately following a single intervention. While self-reported confidence and perceived willingness to use Excel are valuable indicators of engagement and motivation, they do not equate to objective skill mastery. Any inference of skill development is therefore indirect and based on changes in students' reported willingness to engage with Excel tasks. Educators looking to design escape room-based learning tools may wish to consider incorporating objective performance metrics, such as pre/post testing or comparison with control groups, to more rigorously evaluate their impact.

Wider Application of the Excel Escape Room

While the Excel escape room described in this study was designed to address specific skill in first-year undergraduate

chemistry students, the core structure can be modified to support a wide range of disciplines by tailoring tasks to relevant Excel functions. Within STEM fields, additional rooms could incorporate statistical analyses, specialized data processing techniques, or alternative graphing methods.

Beyond Excel skills development, the Excel escape room format could support diverse educational objectives. For instance, an escape room could be designed around risk assessment, where students must correctly associate hazards with chemicals or procedures to unlock the next stage. Alternatively, in non-STEM disciplines, students could engage with assessment criteria by completing a mark sheet for a sample report, encouraging deeper engagement with grading rubrics.

By offering an engaging, self-directed learning environment, the Excel escape room presents a flexible and scalable tool for fostering Excel proficiency across a range of academic contexts.

CONCLUSIONS

This work demonstrates that an Excel-based escape room is a viable, cost-effective tool for introducing Excel skills to chemistry undergraduates. Embedding tasks within Excel ensures students gain direct familiarity with the software while engaging in scaffolded, challenge-based tasks. The Excel escape room thereby provides an immersive learning environment without the need for funding or external software.

Student feedback indicates that this approach can successfully mitigate the intimidation students often feel toward spreadsheet analysis in Excel. Students reported increased self-confidence and a greater willingness to use Excel for future laboratory tasks. The competitive aspect of the design should be implemented with care to avoid student anxiety. Overall positive student survey responses suggest that the core mechanism of self-paced, scaffolded puzzles with timely integrated feedback proved effective in promoting engagement.

The design described here is highly adaptable. The "locks and keys" model can be readily modified for other topics inside and outside of chemistry and is compatible with free software such as Google Sheets or LibreOffice. This makes it a scalable solution for chemistry educators seeking to bridge the digital literacy gap in their curricula.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at <https://pubs.acs.org/doi/10.1021/acs.jchemed.5c01679>.

Supplementary notes on escape room design (PDF)

Survey instrument (PDF)

Escape room file (XLSX)

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Notes

The author declares no competing financial interest.

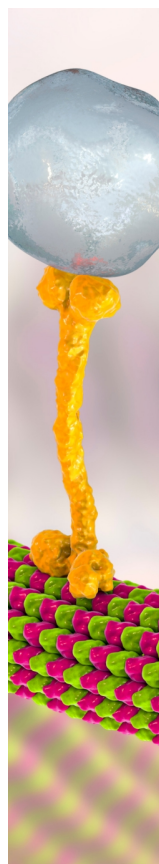
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REFERENCES

- (1) Hansen, S. J. R.; Zhu, J.; Karch, J. M.; Sorrento, C. M.; Ulichny, J. C.; Kaufman, L. J. Bridging the Gap between Instructional and Research Laboratories: Teaching Data Analysis Software Skills through the Manipulation of Original Research Data. *J. Chem. Educ.* **2016**, *93* (4), 663–668.
- (2) Rubin, S. J.; Abrams, B. Teaching Fundamental Skills in Microsoft Excel to First-Year Students in Quantitative Analysis. *J. Chem. Educ.* **2015**, *92* (11), 1840–1845.
- (3) Elvas-Leitão, R.; Moreira, L.; Martins, F. Design of an Excel Spreadsheet To Estimate Rate Constants, Determine Associated Errors, and Choose Curve's Extent. *J. Chem. Educ.* **2006**, *83* (12), 1879.
- (4) Campbell, C. D.; Smallwood, Z. M.; Stewart, M. I. A Self-Directed Workshop for Developing Advanced Data Processing and Analysis Skills in Chemistry Using Microsoft Excel. *J. Chem. Educ.* **2020**, *97* (9), 2635–2642.
- (5) Malone, K. L.; Schunn, C. D.; Schuchardt, A. M. Improving Conceptual Understanding and Representation Skills Through Excel-Based Modeling. *J. Sci. Educ. Technol.* **2018**, *27* (1), 30–44.
- (6) Cooper, P. D. Employing Spreadsheets for Applying Calculus in Upper-Level Chemistry Courses. *J. Chem. Educ.* **2018**, *95* (10), 1890–1893.
- (7) Magalhães, A. L. Introducing Iterative Methods to Undergraduate Chemistry Students—A Spreadsheet-Based Approach. *J. Chem. Educ.* **2020**, *97* (7), 1908–1914.
- (8) Joppa, L. N.; McInerney, G.; Harper, R.; Salido, L.; Takeda, K.; O'Hara, K.; Gavaghan, D.; Emmott, S. Troubling Trends in Scientific Software Use. *Science* **2013**, *340* (6134), 814–815.
- (9) Formby, S. K.; Medlin, D.; Ellington, V. B. Microsoft Excel®: Is It An Important Job Skill for College Graduates? *Information Systems Educ J.* **2017**, *15*, 55–63.
- (10) Lear, B. J. Using ChatGPT-4 to Teach the Design of Data Visualizations. *J. Chem. Educ.* **2024**, *101* (7), 2749–2756.
- (11) Schwarz, J. The use of generative AI in statistical data analysis and its impact on teaching statistics at universities of applied sciences. *Teach Stat* **2025**, *47* (2), 118–128.
- (12) Schlotter, N. E. A Statistics Curriculum for the Undergraduate Chemistry Major. *J. Chem. Educ.* **2013**, *90* (1), 51–55.
- (13) Acosta-Gonzaga, E. The Effects of Self-Esteem and Academic Engagement on University Students' Performance. *Behav Sci. (Basel)* **2023**, *13* (4), 348.
- (14) Saha, P. Effectiveness of in-class excel-based active learning activities for transportation engineering courses. *Front Educ* **2022**, *7*, 1.
- (15) OCR Computer Science (9-1) - J277. <https://www.ocr.org.uk/qualifications/gcse/computer-science-j277-from-2020/> (accessed 2025-02-25).
- (16) AQA GCSE Computer Science. <https://www.aqa.org.uk/subjects/computer-science/gcse/computer-science-8525/specification> (accessed 2025-02-25).
- (17) Pearson Edexcel Computer Science. <https://qualifications.pearson.com/en/qualifications/edexcel-gcses/computer-science-2020.html> (accessed 2025-02-25).
- (18) CCEA GCSE Digital Technology. <https://ccea.org.uk/key-stage-4/gcse/subjects/gcse-digital-technology-2017> (accessed 2025-02-25).
- (19) WJEC GCSE Computer Science. <https://www.wjec.co.uk/qualifications/computer-science-gcse/> (accessed 2025-02-25).
- (20) Marley, S. A.; Siani, A.; Sims, S. Real-life research projects improve student engagement and provide reliable data for academics. *Ecol Evol* **2022**, *12* (12), No. e9593.
- (21) Gray, J. A.; DiLoreto, M. The Effects of Student Engagement, Student Satisfaction, and Perceived Learning in Online Learning Environments. *Int. J. Educ Leadership Prep* **2016**, *11*, 98–119.
- (22) Macnamara, B. N.; Berber, I.; Çavuşoğlu, M. C.; Krupinski, E. A.; Nallapareddy, N.; Nelson, N. E.; Smith, P. J.; Wilson-Delfosse, A. L.; Ray, S. Does using artificial intelligence assistance accelerate skill decay and hinder skill development without performers' awareness? *Cogn Res. Princ Implic* **2024**, *9* (1), 46.
- (23) Losh, E. *Universities must stop presuming that all students are tech-savvy*; Times Higher Education: 04-02–202-, 2021.
- (24) Czaja, S. J.; Charness, N.; Fisk, A. D.; Hertzog, C.; Nair, S. N.; Rogers, W. A.; Sharit, J. Factors predicting the use of technology: findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychol Aging* **2006**, *21* (2), 333–352.
- (25) OFSTED Research Review Series: Computing. <https://www.gov.uk/government/publications/research-review-series-computing/research-review-series-computing> (accessed 2025-12-25).
- (26) Bernacki, M. L.; Vosicka, L.; Utz, J. C. Can a brief, digital skill training intervention help undergraduates “learn to learn” and improve their STEM achievement? *J. Educ Psychol* **2020**, *112* (4), 765–781.
- (27) Basilla, M. A. O. Impact of Microsoft Excel on Student Engagement and Interaction in Grade 11 Physical Science. *Puissant* **2025**, *6*, 2694–2708.
- (28) Deng, X. N.; Yi, S. Individual motivation and self-perception of excel skills learning: An empirical study of first-generation college students and their peers. *J. Account Educ* **2025**, *70*, 100947.
- (29) Ng, W. Can we teach digital natives digital literacy? *Comput. Educ* **2012**, *59* (3), 1065–1078.
- (30) Sailer, M.; Homner, L. The Gamification of Learning: a Meta-analysis. *Educ Psy Rev.* **2020**, *32* (1), 77–112.
- (31) Ortiz-Rojas, M.; Chiluzia, K.; Valcke, M.; Bolanos-Mendoza, C. How gamification boosts learning in STEM higher education: a mixed methods study. *Int. J. STEM Educ* **2025**, *12* (1), 1.
- (32) Bai, S.; Hew, K. F.; Huang, B. Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. *Educ Res. Rev.* **2020**, *30*, 100322.
- (33) Leitão, R.; Maguire, M.; Turner, S.; Guimarães, L. A systematic evaluation of game elements effects on students' motivation. *Educ Inf Technol.* **2022**, *27* (1), 1081–1103.
- (34) Csikszentmihalyi, M. *Flow: The Psychology of Optimal Experience*. Harper & Row: 1990.
- (35) Garris, R.; Ahlers, R.; Driskell, J. E. Games, Motivation, and Learning: A Research and Practice Model. *Simul Gaming* **2002**, *33* (4), 441–467.
- (36) Buendía-Atencio, C.; Pieffet, G. P.; Lorett Velásquez, V. P. WERNER: A Card Game for Reinforcement Learning of Inorganic Chemistry Nomenclature. *J. Chem. Educ.* **2022**, *99* (5), 2198–2203.
- (37) van Dinther, R.; de Putter, L.; Pepin, B. Features of Immersive Virtual Reality to Support Meaningful Chemistry Education. *J. Chem. Educ.* **2023**, *100* (4), 1537–1546.
- (38) Kalogiannakis, M.; Papadakis, S.; Zourmpakis, A.-I. Gamification in Science Education. A Systematic Review of the Literature. *Educ Sci.* **2021**, *11* (1), 22.
- (39) Chen, M. Y.; Tang, J. T. Developing a digital game for excel skills learning in higher education - a comparative study analyzing differences in learning between digital games and textbook learning. *Educ Inf Technol. (Dordr)* **2023**, *28* (4), 4143–4172.
- (40) López-Belmonte, J.; Segura-Robles, A.; Fuentes-Cabrera, A.; Parra-González, M. E. Evaluating Activation and Absence of Negative Effect: Gamification and Escape Rooms for Learning. *Int. J. Environ. Res. Public Health* **2020**, *17* (7), 2224.

- (41) Vorderobermeier, A.; Abel, J.; Sailer, M. Theoretical foundations and approaches in research on educational escape rooms: A systematic review. *Educ Res. Rev.* **2024**, *44*, 100625.
- (42) Barrows, H. S. Problem-based learning in medicine and beyond: A brief overview. *New Dir Teach Learn* **1996**, *1996* (68), 3–12.
- (43) Ryan, R. M.; Deci, E. L. *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*; Guilford Publications: 2018.
- (44) Pozo-Sánchez, S.; Lampropoulos, G.; López-Belmonte, J. Comparing Gamification Models in Higher Education Using Face-to-Face and Virtual Escape Rooms. *J. New Approach Educ Res.* **2022**, *11* (2), 307–322.
- (45) Oforu-Ampong, K. The Shift to Gamification in Education: A Review on Dominant Issues. *J. Educ Technol. Systems* **2020**, *49* (1), 113–137.
- (46) Lam, P.; Tse, A. Gamification in Everyday Classrooms: Observations From Schools in Hong Kong. *Front Educ* **2022**, *6*, 1.
- (47) Lester, D.; Skulmoski, G. J.; Fisher, D. P.; Mehrotra, V.; Lim, I.; Lang, A.; Keogh, J. W. L. Drivers and barriers to the utilisation of gamification and game-based learning in universities: A systematic review of educators' perspectives. *Br J. Educ Technol.* **2023**, *54* (6), 1748–1770.
- (48) Lumsden, J.; Edwards, E. A.; Lawrence, N. S.; Coyle, D.; Munafò, M. R. Gamification of Cognitive Assessment and Cognitive Training: A Systematic Review of Applications and Efficacy. *JMIR Serious Games* **2016**, *4* (2), No. e11.
- (49) Fuchs, K. Challenges with gamification in higher education: A narrative review with implications for educators and policymakers. *Int. J. Change Educ* **2024**, *1* (1), 51–56.
- (50) Krath, J.; Schürmann, L.; von Korfflesch, H. F. O. Revealing the theoretical basis of gamification: A systematic review and analysis of theory in research on gamification, serious games and game-based learning. *Comput. Hum Behav* **2021**, *125*, 106963.
- (51) Feng, L.; Shen, X.; Xie, Z.; Yan, X. How gamification-based course drives online learners' engagement: Focusing on intrinsic motivation and effect mechanism. *Educ Inf Technol* **2025**, *30*, 10943.
- (52) Kam, A.; Umar, I. N. Fostering authentic learning motivations through gamification: A self-determination theory (SDT) approach. *J. Eng. Sci. Technol.* **2018**, *13*, 1–9.
- (53) Sweetser, P.; Wyeth, P. GameFlow: a model for evaluating player enjoyment in games. *Comput. Entertain* **2005**, *3* (3), 3.
- (54) Li, M.; Ma, S.; Shi, Y. Examining the effectiveness of gamification as a tool promoting teaching and learning in educational settings: a meta-analysis. *Front Psy* **2023**, *14*, 1.
- (55) Roth, A.; Ogrin, S.; Schmitz, B. Assessing self-regulated learning in higher education: a systematic literature review of self-report instruments. *Educ Assess Eval Account* **2016**, *28* (3), 225–250.
- (56) Taber, K. S. The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Res. Sci. Educ* **2018**, *48* (6), 1273–1296.
- (57) Dichev, C.; Dicheva, D. Gamifying education: what is known, what is believed and what remains uncertain: a critical review. *Int. J. Educ Technol. Higher Ed* **2017**, *14* (1), 9.
- (58) Ho, J. C.-S.; Hung, Y.-S.; Kwan, L. Y. Y. The impact of peer competition and collaboration on gamified learning performance in educational settings: a Meta-analytical study. *Educ Inf Technol.* **2022**, *27* (3), 3833–3866.
- (59) Liu, Y.-J.; Zhou, Y.-G.; Li, Q.-L.; Ye, X.-D. Impact Study of the Learning Effects and Motivation of Competitive Modes in Gamified Learning. *Sustainability* **2022**, *14* (11), 6626.
- (60) Zainuddin, Z.; Chu, S. K. W.; Shujahat, M.; Perera, C. J. The impact of gamification on learning and instruction: A systematic review of empirical evidence. *Educ Res. Rev.* **2020**, *30*, 100326.
- (61) Almeida, C.; Kalinowski, M.; Uchôa, A.; Feijó, B. Negative effects of gamification in education software: Systematic mapping and practitioner perceptions. *Info Software Technol.* **2023**, *156*, 107142.
- (62) Sepehr, S.; Head, M., Competition as an element of gamification for learning: an exploratory longitudinal investigation. In *Proceedings of the First International Conference on Gameful Design, Research, and Applications*, Association for Computing Machinery: Toronto, Ontario, Canada, 2013; pp 2–9.
- (63) van Gaalen, A. E. J.; Brouwer, J.; Schönrock-Adema, J.; Bouwkamp-Timmer, T.; Jaarsma, A. D. C.; Georgiadis, J. R. Gamification of health professions education: a systematic review. *Adv. Health Sci. Educ Theory Pract* **2021**, *26* (2), 683–711.
- (64) Slamet, T.; Brush, T.; Kwon, K. The Effects of Competition in Gamified Online Discussions on Learners' Behavioral and Cognitive Engagement. *Technol. Knowl Learn* **2025**, *30* (1), 1–27.
- (65) Ding, L. Applying gamifications to asynchronous online discussions: A mixed methods study. *Comput. Hum Behav* **2019**, *91*, 1–11.
- (66) Cao, Y.; Gong, S.-Y.; Wang, Y.-Q.; Zheng, Q.; Wang, Z. How to provide competitors in educational gamification: The roles of competitor level and autonomous choice. *Comput. Hum Behav* **2023**, *138*, 107477.



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