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Escape experience Aeroseum: a classical mechanics escape room

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Abstract
Classical mechanics has long been a conceptually challenging topic for students. Escape Experience Aeroseum offers a novel approach to help address this issue by integrating classical mechanics into an educational escape room (EER). The escape room creatively combines physics with aerospace engineering principles, with the aim of aiding learners in making more sense of classical mechanics concepts through solving interactive, hands-on challenges. In the paper, we discuss the design and educational potential of Escape Experience Aeroseum, including the need for adaptability and appeal across different educational settings. By introducing an EER centered around classical mechanics, this work contributes to the growing interest in developing and evaluating EERs as a possible means to increase students learning, engagement, and interest in physics.

Keywords: educational escape room, game-based learning, classical mechanics, Newtonian mechanics, interactive physics problems, undergraduate physics, upper-secondary school

Supplementary material for this article is available online

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1. Introduction

In line with the rising popularity of escape rooms and the application of its concept to education [1–4], an educational escape room (EER) about classical mechanics (hereafter mechanics) has been developed at the Aeroseum in Gothenburg. Aeroseum is an experience-based activity center in a declassified Swedish Air Force bunker. The center allows visitors to discover the history and development of aviation in its interactive exhibitions (figure 1). It also aims to stimulate young people's interest in science and technology through its educational program for schools.

Many escape rooms have been built targeting education to involve students in interactive and entertaining learning activities involving both body and mind [5–11]. One area suited for tangible physics challenges and puzzles is mechanics, which is typically an introductory course or topic with many conceptual hurdles for students related to force, kinematics, and vectors [12–19]. However, no EER targeting mechanics is present in the current literature [3], and existing games offer little adaptability to new educational settings [4]. To this end, the current study presents a newly developed EER, *Escape Experience Aeroseum*, focusing on interactive mechanics problems targeting the upper-secondary and introductory undergraduate level. The escape room is modular in that problems can be combined in several ways to fit the visiting teachers' needs.

This paper presents an overview of the developed EER, specifically focusing on two mechanics problems. Further, design principles for EERs are discussed with two of the developed challenges as an example. Instructions and an overview of the rest of the developed mechanics challenges are provided in the supplementary material.

2. Escape Experience Aeroseum

In line with traditional escape rooms, the activity starts by introducing a storyline, aiming to provide a sense of immersion. For this EER, the story revolves around the participants having to contact a pilot and provide coordinates on a secret radio frequency on where it is safe to land. Thus, various challenges must be solved, earning the group different codes that ultimately lead to the required information.

Figure 1. A helicopter (Boeing Vertol 107, HKP 4) is one of the exhibits in Aeroseum that visitors can enter and examine from within.

Figure 2. The mission room. Solving the EER includes solving problems throughout Aeroseum and get codes to open various boxes and lockers in the room.

Contrary to traditional escape rooms, the participants are not locked into a confined space. Instead, the goal is to unlock various boxes in the mission room (figure 2). After initially solving two tasks inside the mission room, the next stage is to take on multiple Aeroseum puzzles and mechanics problems, spread throughout Aeroseum. The Aeroseum puzzles consist of finding clues to solve enigmas related to aviation navigation, existing exhibits, or cryptographic problems. The mechanics problems are interactive problems and can be modified depending on the level of the participants by providing partial solutions, clues, or extra information about the physics involved.

As with traditional escape rooms, the tasks in this EER are connected in various ways. The flowchart (figure 3) presents an overview of how

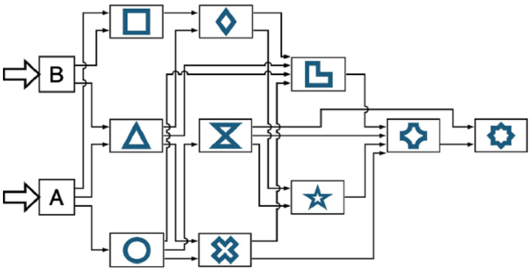

Figure 3. Flowchart highlighting the interconnectedness between the Aeroseum puzzles if playing the full edition. To start things off, participants are faced with two challenges, A and B in the mission room. Solving the Aeroseum puzzles will in turn give participants parts needed to fully complete the mechanics problems. Each symbol is related to one puzzle. For reference, see the full edition manual in the supplementary material.

challenges are connected in a configuration of the EER where all tasks are included. However, how they are linked and which are included is easily modified when preparing the EER. This is essential for it to be relevant both for the general public and relevant for teachers bringing groups of students.

2.1. The mechanics problems

Five tasks focus on mechanics and mechanical engineering. To make the EER thematically fit in Aeroseum, they were designed to connect to aviation and aerospace engineering. The available problems are *gear system, pendulums, motion graphs, friction* and *moment balance and pulleys*. In this paper, *pendulums* and the *motion graphs* will be used as an example. The interested reader may find more information on the mechanics problems in the supplementary material.

2.2. Motion graphs

The objective of the *motion graphs* mystery (figure 4) is to gather information about the motion of an airplane flight, a parachute jump, and a rocket flight from three different texts (available in the supplementary material). Each story provides information about various motion graphs, distance-time, velocity-time, and acceleration-time. The participants should then place the correct graph on the whiteboard for each story. When completing this task, the participants are again rewarded with digits that provide a new set of coordinates.

Figure 4. The motion graphs mystery. From the short stories and information provided, the participants should figure out where each graph should be placed.

2.3. Pendulums

Solving the *pendulums* challenge involves figuring out the length of a pendulum string to have a certain period when released from a small angle. There are three pendulums in total, which, when solved, provide the missing digits to complete the coordinate (figure 5). Each pendulum has a corresponding task card with information about what period the pendulum should have. The clue is a displacement-time graph for the blue (left) pendulum; for the red (middle) pendulum, $T_n = 1.5$ s denotes period; and for the yellow (right) pendulum, the natural frequency is given as $f_n = 1.25$ Hz. The challenge is solved when the participants figure out how much each dial should be turned so that the length of the pendulum gives rise to the corresponding periods. With access to a ruler but no stopwatch, participants must identify and solve an equation connecting the length and period of a pendulum (information about the formula can also be provided with a clue, e.g. figure 6). Then, each arrow points to a missing digit from the coordinate.

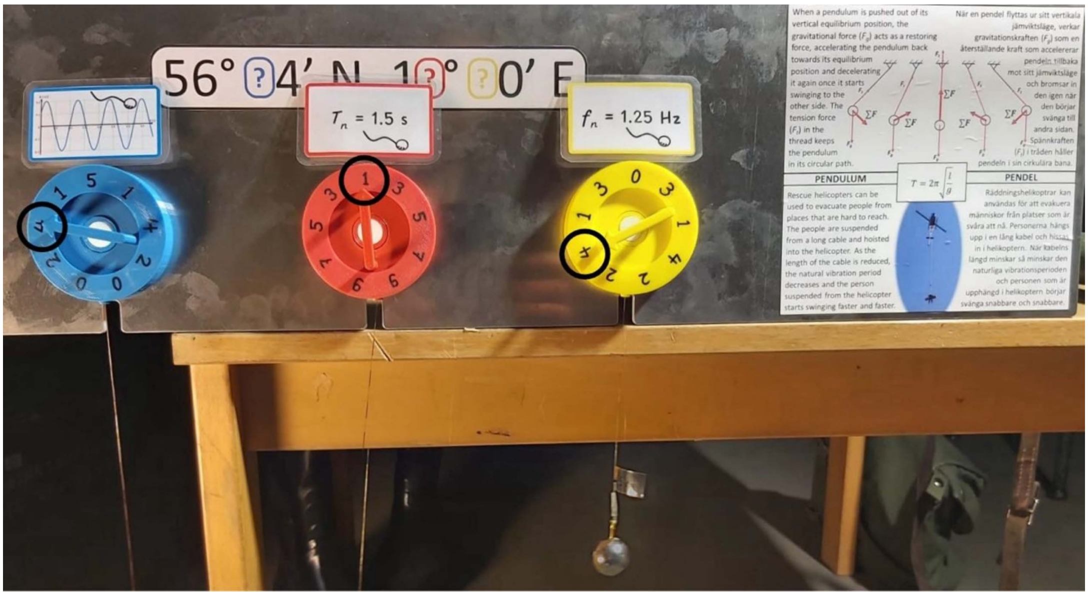

Figure 5. The pendulums challenge. From left to right, there are three spools, blue, red, and yellow, that the participants can spin to vary the length of the wire. At the end of each wire, a spherical mass is attached, with a small note above indicating the mass. To the right, some information about pendulums is provided in English and Swedish. Above each spool, the corresponding clue has been placed regarding what period is sought for each pendulum.

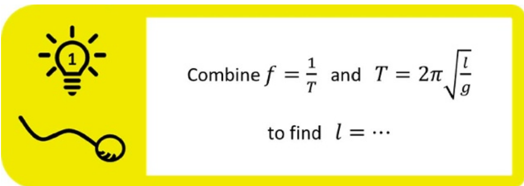

Figure 6. A clue for solving the yellow pendulum that provides the participants with the formulas needed to find the relationship between string length and period.

3. Discussion

By offering several versions of the EER (see supplementary material for a manual and an idea of the *full edition, family edition beginner/advanced, team-building activity*, and *physics edition beginner/advanced*), the target audience is both groups of students visiting Aeroseum as part of a school activity, as well as the everyday curious family or group of friends. The EER being developed at a museum-like activity center can be considered a designed informal learning environment [20]. Having a varied set of activities, both mechanics problems and others, *Escape Experience Aeroseum* opens up possibilities for future studies involving varying populations. However, as no such studies have been conducted yet, the discussion will instead reflect on the two presented mechanics problems and ideas regarding the possible use of the EER by visiting groups of students.

When designing activities that combine games and learning, such as EER, there is a challenge in promoting moving between the real world and the game. Designing a serious persuasive game (i.e. a game that aims to change behavior or attitude and has clear educational goals in mind) that successfully promotes moving between these worlds has been argued to include requiring an integrated design approach [21, 22]. Such a design characterizes the connection between the real world and the game as a transition from the real world and, finally, a transfer back to the real world. By having a thoughtful connection between an overarching persuasive goal, the goal of the game, and learning goal(s), challenges in aligning agendas from the real world and the game are more straightforward to overcome [21].

In analyzing *Escape Experience Aeroseum* using the integrated design approach, with a specific focus on how to connect the persuasive goal, the game goal, and learning goal(s) (figure 7), it is possible to identify several key features. First, the persuasive goal is to give participants a greater appreciation for physics and thus help raise the general interest in physics and mechanical engineering. Second, when using the EER in the context of a group of students taking one of the *physics editions*, learning goals could be related to general problem-solving and teamwork skills and more specific goals concerning the mechanics problems. One such example for the *motion graphs* mystery could be that upon completing the activity, students should be able to construct motion graphs from text descriptions. Focusing on gaining a conceptual understanding of various motion graphs could help students overcome the seemingly challenging task of connecting integrals to graphs in undergraduate physics education [23]. Third, with the overarching game goal being to find coordinates for where a pilot should land, the specific goal in *motion graphs* is to find one set of coordinates leading to the final answer. As the participants can only solve this part of the game by placing the graphs correctly on the whiteboard, the game goal overlaps with the learning goal. Finally, the design of the *motion graphs* mystery also includes having an overarching persuasive goal in mind. The persuasive goal of the EER guides the design of the connection between the game goal and learning goal(s) in the sense that the different stories have been constructed to promote a connection between physics, everyday life, and aviation.

Discussions were held in designing the physics problems to identify possible educational issues regarding the concepts involved. Taking the *pendulums* challenge as an example, the challenge was developed to provide a connection between different representations of the period of a pendulum and the relationship between the period and length of a string. Thus, there is a combination of physical exploration and connection to the commonly used model for pendulums in upper-secondary education, the small angle approximation of a mathematical pendulum.

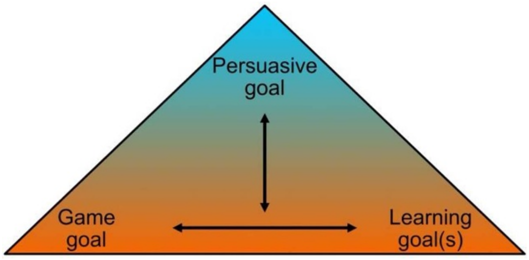

Figure 7. Connecting the various goals when using an integrated design approach. The gradient from blue (persuasive goal) to orange [game goal and learning goal(s)] represents transitioning between the real world and the game world.

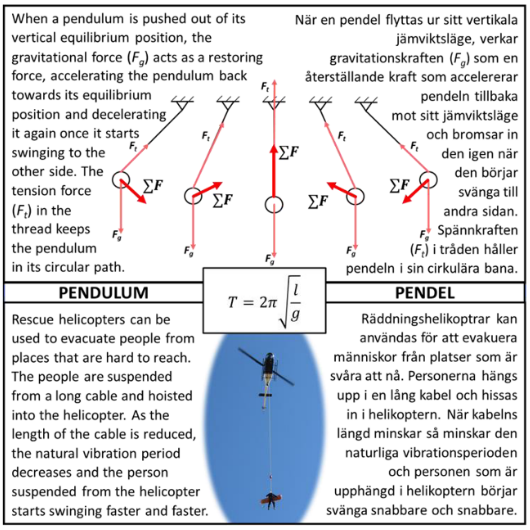

Figure 8. The provided information text in the pendulums challenge is in English to the left and Swedish to the right.

As pendulums are far from trivial, yet deceptively simple [24], it is common for students at various levels to struggle with understanding the phenomenon in subject-correct ways [12–16, 25]. To address the common struggle with connecting and separating forces acting on the mass of a pendulum to its movement, a descriptive text about forces acting on the mass was included (figure 8). As such, there is an additional educational goal embedded in the challenge; exposing participants to a possible different, physically correct view of the direction of the net force acting on a mass at the end.

4. Conclusion

With a growing interest in escape rooms, and in particular, the development of EERs, *Escape Experience Aeroseum* contributes to the growing scientific discussion in several ways. Contributions to the physics education research community are made by developing an EER focusing on mechanics problems that are easily implemented in classroom settings. As such, it opens up the possibility of future investigations regarding *Escape Experience Aeroseum* and how the individual challenges might be valuable inclusions in physics courses on their own. Finally, the discussion suggests an extension of the integrated design approach that can be used and further evaluated when designing serious persuasive games.

Data availability statement

No new data were created or analysed in this study.

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Authors' contribution

Sebastian: Writing—original draft preparation (lead); writing—review and editing (equal); conceptualization (supporting); validation; visualization (equal); supervision (supporting).
Merel: Writing—original draft preparation (supporting); writing—review and editing (supporting); conceptualization (lead); visualization (equal); investigation.
Jonathan: Writing—review and editing (equal); conceptualization (equal); supervision (equal).
Magnus: Writing—review and editing (equal); conceptualization (equal); supervision (equal).
Jonas: Writing—review and editing (equal); conceptualization (equal); project administration; supervision (equal).

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References

[1] Veldkamp A, van de Grint L, Knippels M-C P J and van Joolingen W R 2020 Escape education: a systematic review on escape rooms in education *Educ. Res. Rev.* **31** 100364
[2] Veldkamp A, Knippels M C P J and van Joolingen W R 2021 Beyond the early adopters: escape rooms in science education *Front. Educ.* **6** 622860
[3] Lathwesen C and Belova N 2021 Escape rooms in STEM teaching and learning—prospective field or declining trend? A literature review *Educ. Sci.* **11** 308
[4] Piñero Charlo J C, Belova N, Quevedo Gutiérrez E, Zapatera Llinares A, Arboleya-García E, Swacha J, López-Serentill P and Carmona-Medeiro E 2022 Preface for the special issue "trends in educational gamification: challenges and learning opportunities" *Educ. Sci.* **12** 179
[5] Dietrich N 2018 Escape Classroom: the leblanc process—an educational "escape game" *J. Chem. Educ.* **95** 996–9
[6] Avargil S, Shwartz G and Zemel Y 2021 Educational escape room: break Dalton's code and escape! *J. Chem. Educ.* **98** 2313–22
[7] Gómez-Urquiza J L, Gómez-Salgado J, Albendín-García L, Correa-Rodríguez M, González-Jiménez E and Cañadas-de la Fuente G A 2019 The impact on nursing students' opinions and motivation of using a "nursing escape room" as a teaching game: a

descriptive study *Nurse Educ. Today* **72** 73–76
[8] Sánchez-Martín J, Corrales-Serrano M, Luque-Sendra A and Zamora-Polo F 2020 Exit for success. Gamifying science and technology for university students using escape-room. A preliminary approach *Heliyon* **6** e04340
[9] Vörös A I V and Sárközi Z 2017 Physics escape room as an educational tool *AIP Conf. Proc.* **1916** 050002
[10] Macías-Guillén A, Díez R M, Serrano-Luján L and Borrás-Gené O 2021 Educational hall escape: increasing motivation and raising emotions in higher education students *Educ. Sci.* **11** 527
[11] Kuo H-C, Pan A-J, Lin C-S and Chang C-Y 2022 Let's escape! The impact of a digital-physical combined escape room on students' creative thinking, learning motivation, and science academic achievement *Educ. Sci.* **12** 615
[12] Clement J 1982 Students' preconceptions in introductory mechanics *Am. J. Phys.* **50** 66–71
[13] Reif F and Allen S 1992 Cognition for interpreting scientific concepts: a study of acceleration *Cogn. Instr.* **9** 1–44
[14] Shaffer P S and McDermott L C 2005 A research-based approach to improving student understanding of the vector nature of kinematical concepts *Am. J. Phys.* **73** 921–31
[15] Galili I and Bar V 1992 Motion implies force: where to expect vestiges of the misconception? *Int. J. Sci. Educ.* **14** 63–81
[16] Santos-Benito J V and Gras-Marti A 2005 Ubiquitous drawing errors for the simple pendulum *Phys. Teach.* **43** 466–8
[17] Twigger D, Byard M, Driver R, Draper S, Hartley R, Hennessy S, Mohamed R, O'Malley C, O'Shea T and Scanlon E 1994 The conception of force and motion of students aged between 10 and 15 years: an interview study designed to guide instruction *Int. J. Sci. Educ.* **16** 215–29
[18] Bouzid T, Kaddari F and Darhmaoui H 2022 Force and motion misconceptions' pliability, the case of Moroccan high school students *J. Educ. Res.* **115** 122–32
[19] Anggoro S, Widodo A, Suhandi A and Treagust D F 2019 Using a discrepant event to facilitate preservice elementary teachers' conceptual change about force and motion *EURASIA J. Math. Sci. Technol. Educ.* **15** em1737
[20] Bennett M B, Fracchiola C, Harlow D B and Rosa K 2023 Informal learning in physics *The International Handbook of Physics Education Research: Teaching Physics* (AIP Publishing LLCMelville) pp 12-1–28
[21] Veldkamp A, Rebecca Niese J, Heuvelmans M, Knippels M C P J and van Joolingen W R 2022 You escaped! How did you learn during gameplay? *Br. J. Educ. Technol.* **53** 1430–58
[22] Veldkamp A, Merx S and van Winden J 2021 Educational escape rooms: challenges in aligning game and education *Well Played* **10** 109–35
[23] Pendrill A-M and Ouattara L 2017 Force, acceleration and velocity during trampoline jumps—a challenging assignment *Phys. Educ.* **52** 065021
[24] Schwarz C 1995 The not-so-simple pendulum *Phys. Teach.* **33** 225–8
[25] Dandare K 2018 A study of conceptions of preservice physics teachers in relation to the simple pendulum *Phys. Educ.* **53** 055002

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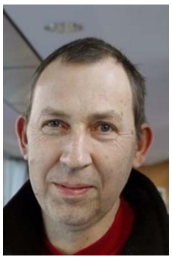

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