Research Protocol: Escape to Learn — Exploring Non-linear Puzzle-Based Learning in Computing Education

1. Introduction and Background

1.1. Rationale

Student engagement and deep conceptual understanding remain challenging in technically demanding subjects like Artificial Intelligence (AI) and Machine Learning (ML). Traditional teaching methods often fail to maintain interest or connect theory to practice effectively. Inspired by escape room pedagogy, this project explores non-linear, puzzle-based learning as a playful and immersive approach to enhance engagement and learning outcomes. There is a gap in scalable, flexible, and subject-specific implementations of such pedagogies, especially integrating gamification alongside traditional methods. This study aims to fill that gap by developing and evaluating unified learning resources embedded with puzzle-based activities across AI/ML curricula.

1.2. Research Questions

1. RQ1: How does the integration of non-linear, puzzle-based activities in AI/ML education affect student engagement?
2. RQ2: Does participation in these activities improve students' conceptual understanding of AI/ML topics?
3. RQ3: What barriers and facilitators do educators encounter when implementing this pedagogy, and how do institutional contexts influence delivery?

2. Study Design and Methodology

2.1. Study Design

This is a mixed-methods, multi-institutional collaborative study involving the co-design, pilot testing, and evaluation of non-linear, puzzle-based learning activities embedded in AI/ML curricula. Both quantitative (pre/post assessments, surveys) and qualitative (educator reflections, student feedback) data will be collected.

2.2. Participants

The target population includes AI/ML students and educators across participating institutions in Great Britain. Participants will be selected from course cohorts delivering the standardised six-lecture curriculum developed for this project. Sampling will aim to balance representation across regions (England, Scotland, Wales, Ireland) to ensure generalisability.

2.3. Standardised Participant Protocol and Course Design Framework

To ensure the integrity and comparability of outcomes across all participating institutions, a minimum protocol must be followed. First, sample variation must be carefully managed to maintain consistency across different geographic locations. This includes ensuring proportional representation from regions such as England, Ireland, Scotland, and Wales, which helps prevent regional bias and supports the development of broadly generalizable conclusions. In parallel, a unified learning experience will be established through the development of a standardised six-lecture course structure. This structure must be uniformly implemented across all sites, with materials designed to be homogeneous and aligned with the students' existing level of knowledge. This approach avoids variation in content difficulty and ensures that all participants engage with the same learning objectives, the same topics and instructional depth. Teaching materials will be divided into two distinct methodological categories: traditional materials, which include conventional lectures and assessments, and gamification-based materials, which incorporate interactive, puzzle-oriented activities such as escape room exercises. Each institution is required to deliver the materials according to its assigned methodology, thereby enabling a robust and fair evaluation of the effectiveness of each teaching approach.

2.4. Ethical Framework and Compliance

Ethical integrity is central to the design and implementation of this study. All procedures will be guided by established ethical standards to protect the rights, privacy, and well-being of participants.

Prior to any data collection, all participants—including students and educators—will be fully informed about the study's aims, procedures, potential risks, and anticipated benefits. Clear and accessible consent forms will be provided, outlining participants' rights, including the right to withdraw from the study at any time without penalty. This ensures voluntary participation and transparency throughout the research process.

To safeguard participant privacy, all data will be anonymised before analysis. Personal identifiers will be stored securely and separately from research data, with access restricted to authorised personnel only. Confidentiality protocols will strictly adhere to GDPR regulations and institutional data protection policies, ensuring that sensitive information is handled responsibly and ethically.

Ethical approval will be obtained from the Institutional Review Board (IRB) or ethics committee of each participating institution prior to the commencement of the study. This process will follow best practices for educational research, including guidelines such as those provided by Imperial College London. Securing local ethical clearance ensures that the study meets the standards required for responsible academic inquiry.

2.5. Evaluation Matrices

To comprehensively assess the effectiveness of the intervention and the depth of student engagement, a mixed-methods evaluation framework will be employed. This framework integrates both quantitative and qualitative approaches, ensuring a multidimensional understanding of learning outcomes and participant experiences.

The quantitative assessment component will focus on measuring learning gains through standardised pre- and post-activity evaluations. These may include quizzes, tests, and concept checks targeting core AI/ML concepts. To ensure consistency and comparability across different sites and cohorts, all assessments will follow a unified scoring methodology. This allows for reliable cross-institutional analysis and supports evidence-based conclusions about the intervention's impact on knowledge acquisition.

Complementing this, the qualitative evaluation will explore student engagement and interaction in greater depth. Data will be collected through observational notes, open-ended student reflections, and instructor logs or interviews. These methods will capture nuanced behaviours such as voluntary collaboration, problem-solving strategies, and emotional responses to learning activities. Such insights are essential for understanding how students interact with both the content and their peers, beyond what test scores can reveal.

To further standardise engagement measurement, validated survey instruments will be used to assess behavioural, emotional, and cognitive dimensions of engagement. Tools such as the Student Engagement Questionnaire, or appropriately adapted versions, will be administered across all participating institutions. Agreement on the use of these standardised instruments is crucial to maintain consistency and ensure the validity of the collected data.

All evaluation activities will be conducted in accordance with strict ethical guidelines, including informed consent, confidentiality, and secure data handling. Each institution is responsible for securing local ethics approval prior to initiating any data collection, thereby upholding the integrity and ethical standards of the research.

2.6. Data Analysis

Following data collection, a structured analysis process will be undertaken to interpret the findings. Quantitative data will be analysed using both descriptive and inferential statistical methods, such as paired t-tests and correlation analysis, to evaluate learning gains and changes in engagement across cohorts and sites. These techniques will help determine the statistical significance and practical impact of the intervention.

Meanwhile, qualitative data will be examined through thematic analysis to uncover patterns related to implementation challenges, best practices, and contextual influences. This approach will allow researchers to identify recurring themes and insights that may not be evident through numerical data alone.

Together, these analytical strategies will provide a comprehensive understanding of the intervention's effectiveness, combining measurable outcomes with rich, contextual interpretation.

2.7. Dissemination

The findings of this project will be disseminated through multiple academic and practical channels. These include presentations at leading conferences such as UKICER, publication in peer-reviewed journals, and the development of an open-access toolkit. The toolkit will focus on designing non-linear, puzzle-based learning experiences in computing education, making the project's insights accessible to a broader educational community.

This project is designed to generate practical, evidence-based resources that educators can use to enhance student engagement and learning in AI/ML. By validating active, game-inspired pedagogical strategies, the project aims to influence institutional teaching practices and promote the adoption of innovative methods across STEM disciplines. The broader impact includes fostering more interactive and inclusive learning environments that support diverse student needs.

2.8. Project Management

The project will be managed by a collaborative network of educators, researchers, and instructional designers from multiple institutions. Coordination will be supported through shared digital platforms for co-design, communication, and data exchange. Funding and budget allocations will be managed in alignment with institutional contributions, ensuring transparency and equitable resource distribution.

References

A comprehensive list of cited literature will be maintained, covering foundational and contemporary works on non-linear pedagogy, puzzle-based learning, and gamification in higher education. These references will support the theoretical and methodological grounding of the project.

Appendices

Supporting materials will be provided in the appendices, including consent forms, survey instruments, curriculum outlines, and educator reflection templates. These documents will offer practical tools for implementation and replication, enhancing the project's transparency and utility for future research and practice.