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

1. **Introduction and Background**
   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. **Literature Review**

Existing research supports active, game-inspired learning as a means to increase motivation and improve conceptual grasp in STEM fields. Puzzle-based learning aligns well with AI/ML workflows and fosters exploratory, collaborative problem-solving. However, most educational escape room implementations are linear and centrally controlled, limiting authenticity and scalability. Prior studies (e.g., Falkner et al., 2010; Eukel et al., 2020; Gronseth et al., 2025) emphasize the benefits of non-linear, embedded learning activities but highlight the need for further cross-institutional evaluation and adaptation to diverse teaching styles.

* 1. **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?
4. **Study Design and Methodology**
   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.

* 1. **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 standardized six-lecture curriculum developed for this project. Sampling will aim to balance representation across regions (England, Scotland, Wales, Ireland) to ensure generalizability.

* 1. **Minimum Protocol for Project Participants**

1. **Consistency in Sample Variation**
2. Variation of samples across different locations must be controlled and balanced.
3. Ensure proportional representation of samples from different regions (e.g., England, Ireland, Scotland, Wales) to avoid bias.
4. Aim for representative sample distribution to support generalized conclusions.
5. **Unified Learning Material Development**
6. Develop a standardized six-lecture course structure to be uniformly applied across all participant locations.
7. All participants must adhere to this fixed course structure to ensure consistency in learning objectives and content delivery.
8. **Division of Teaching Materials by Methodology**
9. Clearly categorize course materials into two methodologies:
10. Traditional Teaching Materials: Conventional lectures and assessments.
11. Gamification-based Materials: Interactive, puzzle-based activities such as escape room exercises.
12. Each participant institution must deliver these materials according to their respective methodologies for accurate comparative evaluation.
13. **Use of Evaluation Matrix**

Implement a mixed-methods evaluation framework combining quantitative and qualitative assessments to gauge effectiveness and engagement comprehensively.

1. **Quantitative Assessment of Learning Gains:**
2. Conduct standardized pre- and post-activity assessments (e.g., quizzes, tests, concept checks) on core AI/ML concepts.
3. Apply standardized scoring methods for reliable comparisons across different sites and cohorts.
4. **Qualitative Evaluation of Engagement and Interaction:**
5. Employ qualitative data collection methods including:
   * + Observational notes documenting student participation and interaction.
     + Reflective feedback from students via open-ended surveys or written reflections.
     + Instructor observations, logs, or interviews noting engagement and challenges.
6. Examples include noting frequency of voluntary collaboration or analysis of reflective writings regarding problem-solving strategies.
7. **Standardized Engagement Surveys and Metrics:**
8. Utilize validated engagement surveys capturing behavioural, emotional, and cognitive dimensions of engagement.
9. Examples include the Student Engagement Questionnaire or appropriately adapted survey instruments.
10. All participating institutions must agree on standardized instruments to maintain consistency and validity of data.
11. **Data Triangulation and Interpretation:**
12. Integrate quantitative test scores with qualitative insights from surveys, observations, and reflections.
13. Ensure triangulated data analysis to robustly evidence the effectiveness of the intervention.
14. **Ethical Considerations and Data Management:**
15. Adhere strictly to ethical guidelines, including informed consent, confidentiality, and secure data handling.
16. Obtain necessary local ethics approvals prior to data collection activities.
    1. **Data Collection**

* Pre- and post-activity conceptual assessments
* Student engagement and perception surveys
* Performance metrics aligned with course assessments
* Structured educator reflections and interviews post-implementation
  1. **Data Analysis**

Quantitative data will undergo descriptive and inferential statistical analysis (e.g., paired t-tests, correlation analysis) to assess learning gains and engagement changes. Qualitative data will be analysed thematically to identify implementation challenges, best practices, and contextual influences.

* 1. **Timeline**
* **Sep 2025**: Project kick-off workshop and ethics approval submission
* **Oct-Dec 2025**: Co-design of learning materials and survey instruments
* **Jan-Feb 2026**: Pilot testing of puzzle-based activities
* **Mar-Jun 2026**: Full implementation and data collection
* **Jul-Aug 2026**: Data analysis and interpretation
* **Sep 2026**: Dissemination of findings (conference presentations, publication)

1. **Ethical Considerations**
   1. **Informed Consent**

Participants (students and educators) will be informed about the study aims, procedures, risks, and benefits. Consent will be obtained prior to data collection, with clear information on the right to withdraw at any time without penalty.

* 1. **Confidentiality and Anonymity**

Data will be anonymized before analysis. Personal identifiers will be stored securely and separately from research data. Confidentiality protocols will comply with GDPR and institutional policies.

* 1. **Ethical Approval**

Ethical approval will be sought from each participating institution’s IRB or ethics committee before study commencement, in line with best practices for educational research (Imperial College London guidelines).

1. **Dissemination**
   1. **Plans for Publication**

Findings will be disseminated through academic conferences (e.g., UKICER), peer-reviewed journal articles, and an open-access toolkit for designing non-linear puzzle-based learning in computing education.

* 1. **Impact and Application**

This project aims to provide educators with validated resources and evidence-based strategies to enhance student engagement and learning in AI/ML. The insights gained will inform institutional teaching practices and encourage adoption of active, game-inspired pedagogies in STEM education more broadly.

1. **Other Important Sections**
   1. **Project Management**

The project team comprises a network of educators, researchers, and instructional designers from multiple institutions. Resources include collaborative platforms for co-design and data sharing. Funding and budget allocations will be coordinated according to institutional contributions.

**References**

A full list of cited literature will be maintained, including key works on non-linear pedagogy, puzzle-based learning, and gamification in higher education.

**Appendices**

Supporting documents such as consent forms, survey instruments, curriculum outlines, and educator reflection templates will be provided.