Explainable, AI-supported, unsupervised game-based simulation for improving software engineering project management learning

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Abstract

In the problem of teaching project management, two approaches are used - unsupervised, where the student independently explores the knowledge, and supervised, where it is done under the oversight of a teacher. However, unsupervised approaches struggle with lower material assimilation and explanation of more complex concepts, while the teacher's availability bottlenecks supervised approaches' scalability. This paper proposes a hybrid solution integrating Generative AI (GenAI) to combine the scalability of unsupervised learning with the effectiveness of supervised methods. Firstly, a game-based simulation of a Software Development Project Management scenario was conducted with 67 students to understand the problem better. It highlighted students' high engagement and confirmed the need for feedback. Secondly, an initial validation using manually prepared queries showed promising potential in GenAI providing feedback and eliminating the need for teachers' engagement. However, it underlined the need to curate the answer scope and maintain the context of the simulation progress for such solutions to be effective. To answer those problems, two approaches are proposed: one leveraging a specialised Small Language Model and another employing a Large Language Model with Retrieval-Augmented Generation.

Keywords: GenAI, Game-based learning, project management, education.

1. Introduction and Related Works

In project management education, a significant problem is to find a way to present complex phenomena realistically and engagingly. One of the solutions that has been considered promising in both higher education and industry is Game-Based Learning (GBL) methods, including educational games and simulations with gamification elements. GBL allows for learning by doing, which is essential when learning complex project management phenomena, and can also maintain motivation to learn and interest [3], [6, 7]. Two possible approaches are in use [1] - unsupervised[1], where the student independently explores the knowledge based on materials and aids, and supervised, where the teacher supervises the learning and explains what is needed. The disadvantage of the first solution is a much lower assimilation of the material, self-reinforcement of prior predictions and a more significant number of errors made by the student. Also, it is difficult to explain more advanced concepts. In the case of the second solution, the problem is the need for the teacher's very active involvement, which, in practice, makes it possible only to be used in small groups. [1, 2], [8]

Studies [3], [7] show that using GBL methods in project management education can capture and maintain students' attention if they are complex enough and provide challenge and excite-

[1] Often denoted as "perceptual learning without feedback" in the human study process articles.

ment. An unintentional consequence of complex simulations and games found in most of the studies is that students need to try the game several times to understand the rules and game mechanics, and only later can they focus more on the game and learning. That initial lack of understanding of complete rules and direct reference to real-world situations can cause detachment and lower the learning value of the simulation, raising the importance of teachers' supervision in more complex games. These observations are consistent with conclusions drawn from extensive meta-analyses on using games, simulations and gamification in project management [4, 5].

The obvious conclusion is that a solution that retains both approaches' advantages while minimising their disadvantages is needed. This article proposes a hybrid solution combining content matching and content translation of supervised learning with ability to train multiple people from unsupervised learning. Generative artificial intelligence (GenAI) is proposed to achieve this goal. Query engineering techniques allow the application to supplement students with something more than aids, explaining their errors, presenting conclusions and correlations between decisions and personalising content when needed. There are some proposals for using GenAI in simulation, but only as agents for interaction, not for explaining the simulation and providing feedback.

2. Understanding the Problem

To better understand the problem, the authors prepared an unsupervised prototype of a game-based software development project management (SDPM) simulation, which was successfully used in the past during teacher-supervised sessions to conduct the study. The simulation is based on a simplified project of designing and implementing a Student Information System. This topic has been selected to provide a universal domain that all participants should understand at least on a fundamental level, as they use such a system regularly.

During the simulation, students make decisions regarding the execution of subsequent tasks (planned and unplanned), going through the phases of Analysis, Design, Implementation, Testing and Deployment, while managing the project budget, remaining time and client satisfaction. To help them, the visualisation of the planned work is used in the form of a Work Breakdown Structure (WBS) diagram, with visible estimated cost and required time for planned tasks. Decisions made during the earlier phases of the project influence the later scenarios, changing the probability of specific results or adding new unplanned tasks. Due to the results being partially random, the simulation can be performed multiple times by the same student and showcases the risk management aspect of PM.

To check students' experiences during interaction with an unsupervised simulation, a survey[2] was prepared, and the study was conducted on master's students. All participants had previous experience working on small student projects, programming, and creating applications, although on various levels of experience. All participants also had theoretical foundations of the software life cycle and knowledge of software project management in traditional methodologies. Students willing to participate were given the time to go through the simulation and complete the survey comfortably.

The survey consisted of 8 closed and 3 open-ended questions. The closed questions were obligatory and used a Likert scale to express participants' opinions on provided statements regarding students' improvement (questions 1 to 5) and experience with this form of learning (questions 6 to 8). The open-ended questions were voluntary and asked what elements were helpful, what was missing and provided an opportunity to share any additional thoughts and comments regarding the experience.

The survey was attended by 67 students and achieved a high engagement level, with all students finishing the simulation and filling in the obligatory closed questions, 53 filling in at

[2]Survey questions translated into English available at: https://forms.office.com/e/dq0NvqwNmr

least one of the optional open questions, and 33 answering every question, of whom 13 wrote additional comments that the adopted form of the simulation was interesting and engaging.

The majority of students found the simulation helpful (73,6%) and useful for showing SDPM problems (78%); highly valued the educational part of showcasing the effects of earlier planning (85,3%), risk management (69,1%), analysis (80,8%). Virtually all students responded positively to the interactivity of the simulation (98,5%), stated that they would like to play the extended version again (88,2%) and that receiving additional personalised feedback would help them significantly (94,1%).

In open questions, many students pointed out that they would prefer to see a more complex simulation with more factors, problems, tools, and a greater random element (Student Christopher said "adding wider ranges or more randomness to the parameters would make the simulation even more realistic"). It was very noticeable that some students pointed out issues with understanding some tools during the simulation, and sometimes unexpected consequences of decisions (Student Jakob said he was lacking "information about the impact of previous decisions on subsequent ones"), or a too-simplified simulation and a random element being too small, which otherwise would be a greater challenge for them. Some people went through the simulation two or three times, testing the boundary conditions.

3. Proposed Solution - Hybrid Approach

Initial Idea Validation: Based on the simulation and survey results, a low-fidelity prototype was prepared using GenAI with basic query engineering techniques to present conclusions, feedback and explain errors. As an initial prototype, the teacher manually prepared the query after each student's question regarding the simulation and presented the answer to the student. The initial results showed potential, despite not being sufficient. The generated answers provided explanations related to the problem and preserved the context, losing it only after around 4–5 questions, after which GenAI started to provide more general answers. Additionally, many of the initial GenAI's answers were too long, making them difficult for the student to understand fully. This quick test showed that the GenAI-supported explanations could be successfully applied with the application of better techniques to curate the answer scope and reset the context after each decision.

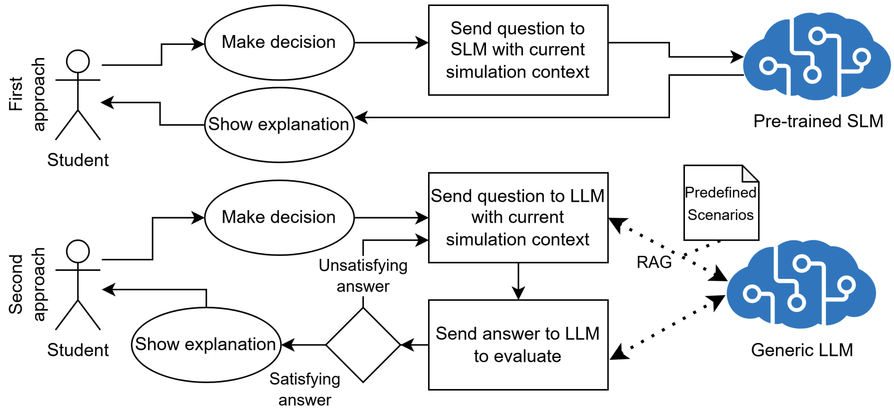

Fig. 1. First and second proposed solution

Proposed Solutions:

In order to improve the quality of feedback, two fully automated, unsupervised solutions presented in Fig.1 are proposed, both of which have shown promising results during the initial implementation. In the first approach, the Small Language Model (SLM) is used instead of LLM, but pre-trained so that answers are directly related to the simulation and not general, as

LLMs tend to do. Also, the issue of hallucinating, which threatens to make students learn incorrect things, could be minimised that way. In the second approach, the need to pretrain the model is removed. Instead, Retrieval-augmented generation (RAG) is added between simulation and GenAI to preserve the context during multiple questions, improve the quality of the answers, and shorten them, allowing for easier understanding. To further refine the answer, LLM would curate itself, evaluating given answers before submitting them to students. Both solutions have their advantages, which are worth thoroughly testing experimentally, where feedback from the language model will occur during the decision-making process when the user receives information about the consequences of their choice. Additionally, students will be able to ask the provided chatbot questions during the simulations to fill in the gaps in their knowledge.

4. Conclussions

The study lays the groundwork for further investigation into the use of GenAI to facilitate engaging and scalable unsupervised game-based simulations by providing explanations for students' decisions, problems and results. The performed survey study showed a strong need for explainable unsupervised game-based simulation for teaching, with 98,5% students agreeing that the interactive aspect of the game helped with their engagement in the lesson and 94,1% identifying real-time feedback as an important addition. Based on identified problems and initial results of a prototype testing, two complex solutions using GenAI have been presented, first using purpose-trained SLM, allowing for easy local deployments, and second using general LLM with RAG mechanisms for possibly easier cloud deployment without the need to retrain the model. In the future, further experimental investigation into both proposed solutions is required.

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