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Improving the Teaching of Artificial Intelligence Through Project-Based Learning on a Board Game

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Abstract. Traditional university lessons do not provide students with the opportunity to put theoretical concepts into practice. Project-Based Learning is designed to involve students through the proposition of real-word problems in the form of a project. The main objective of this work is to improve several aspects of the student's learning experience (e.g., their motivation and interest) through practical experience during a master degree course in Artificial Intelligence. We propose an application of Project-Based Learning through the use of a game-based competition. The experience is designed as an activity that takes place in parallel with respect to the usual lessons. Then, we assessed the significance and the impact of this approach, from the educational point of view, through questionnaires proposed to the students involved. The results of a 3-year study involving more than 200 students are positive. Students reacted favorably to the experience: they think this experience improved their knowledge of AI, their motivation, and their skills. The competitive aspect is considered beneficial from multiple perspectives. Finally, the design of the experience seems to be robust and remains effective in a setting of remote lectures.

Keywords: Artificial Intelligence, Higher Education, Computer Science and Engineering, Project-based Learning, Board Game

1. Introduction

The widespread use of Artificial Intelligence (AI) and its rapid development has fostered the need for new forms of teaching. The rising need to ease the understanding and design of AI systems, present not only in schools and universities but also in industry, can be addressed through practical experiences, which have been observed to have a positive impact on the learning process of students [55,47].

The main objective of this work is to improve the learning experience of students through the application of Project-Based learning (PBL) in an AI university course. Our purpose is to propose an activity different from traditional frontal lessons and coding sessions to improve several aspects of the students' experience, such as their interest, their motivation, and their engagement.

We present a structured experience during the course by allowing the students to develop a solution for a specific, well-defined, and adequately challenging problem: code an AI software player capable of playing the Tablut board game. We design the experience following the principles of PBL, such as promoting collaborative learning and encouraging students' choices, and propose it as an optional group activity that takes place in parallel with respect to the usual lessons.

We choose to use Tablut as board-game since we consider it particularly fit for our purpose. Tablut is

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a little-known Nordic ancient board game where two players with asymmetric roles, alternate in moving their checkers on a 9 x 9 square board. The defender must move their king from the center of the board towards the edges with the aid of its 8 companions, thus escaping the attacker's attempts to capture it with its 12 checkers. Checkers are considered captured when they are surrounded on two opposite sides by the checkers of the opponent, although there are several exceptions to this rule. Unfortunately, there is little information available in the literature for this family of Nordic and Celtic games. We designed the game engine mostly following the work of [1].

We collect the students' perceptions concerning the learning processes and the perceived impacts of this approach through technical and qualitative questionnaires. More in detail, the inquiry focused on analyzing students' point of view about how the proposed project impacted (i) their technical knowledge of AI, (ii) their motivation, (iii) and their soft skills. Motivated by the open debate regarding the effects of competitive environments [39,32], (iv) we have also faced the challenge to question if structuring the experience as a competition can be beneficial to learning and motivation. Finally, since our study includes the years during which COVID-19 extraordinary safety measures and regulations were in place, (v) we have analyzed if and how these solutions affected the method and the development of the research.

The results gathered over three years and six iterations of the experience show a positive involvement of the participant, with increased levels of motivation and investment in the course. Most students also consider the experience beneficial for the learning of the subject and the development of personal skills. The study highlighted also some of the critical aspects of the challenge which must be considered for future improvements.

2. Related Work

2.1. Educational Approaches

The experience was designed by adopting a project-based learning strategy as a non-compulsory part of an AI master's course that students voluntarily joined to acquire AI knowledge through practical activities. This learning experience required the participating students to activate meta-reflexive approaches to their learning process, evaluating the impact from many perspectives, such as subject learning, interest and motivation, and personal skills development. Some researchers [25,29,51] suggested that grades used as an incentive elicited greater assignment completion than when no incentive was used. Based on that, the experience was designed by adopting that each student participating in the activity until the end is awarded an extra bonus points on their final score on the subject. It is therefore appropriate to take a step back and illustrate the pedagogical approaches aimed at enhancing the experiential and participatory learning processes underlying this experience.

John Dewey [20] already paid attention to the relationship between experience and education: in his view, students' learning is ignited by direct experience which is the event that activates prior knowledge already present in the students' minds. The active participation of students in the learning process allows them to interact with the context through experience, constructing, re-mediating, and re-adapting their own knowledge. Thus, education could be considered an active process where students can interact with the context, and possibly modify it. Also, Lev Vygotsky [61] points out that individuals are influenced by the social and cultural context, considering learning as a process that is first social and then individual. Moreover, according to Piaget [48], the learner is not passive to the influences of the context but, rather, an active constructor of his own knowledge. The negotiation of meanings with contexts also takes on particular importance in Bruner's thought [5], which sums up the biological characteristics of Piaget's thought and the socio-cultural characteristics of Vygotsky's. The didactic perspective of Constructivism [50] is centered on certain principles of active pedagogy and in particular on participation and social practices. Biggs et al. [4] distinguish instructional pedagogies, which focus on the transmission of content, from constructivist pedagogies that encourage active engagement. The authors emphasize the importance of "constructive alignment" between learning outcomes, the design of learning activities, and the assessment of learning. Constructivism is an epistemological orientation according to which knowledge is acquired through an active building process, culturally situated and socially negotiated: the student actively participates in building knowledge within a participatory context [40].

While constructivism emphasizes how individuals actively build knowledge, social constructivist approaches pay attention to the social contexts in which the learning process takes place. Learning, which is strongly influenced by social relations, is considered the result of two factors: cooperation with others (social factor) and task characteristics (environmental factor). Therefore, the acquisition of knowledge is the result of group interaction: an individual's learning is the result of a working group that arises from the comparison and cooperation of interdependent groups, and the use of interpersonal communication methods [34].

One of the learning approaches that reflect the theory of constructivism is project-based learning (PBL) [33]. PBL is a student-centered and inquiry-based instructional design approach that foresees students involved in a process of learning conveyed by the active exploration of real-world problems which are proposed to them in the form of projects [41]. PBL approaches involve students, working alone or in a group, to realize an original artifact or product by following a process in which they can interconnect previous knowledge and current experiences with their past experiences. This educational method develops the dimensions of relationships, dialogue, reflection, and critical analysis.

The word "project" deserves clarification: one of the founders of this didactic strategy is Kilpatrick [35], who introduced the concept of "project method". According to Kilpatrick, a project is a "wholehearted purposeful activity proceeding in a social environment". Projects stimulate students to identify a solution to a problem through a practical experience enriched by social interaction with their peers. According to the author [36], the steps to develop a project are four: (i) Purpose: the identification of the activity's purpose; (ii) Plan: the planning; (iii) Execute: the implementation of actions to achieve the predefined objectives; (iv) Judge: the evaluation of the project results.

In more recent times, project methods promoted the definition of PBL as an educational strategy that engages students in developing knowledge and skills through a structured inquiry process with well-structured tasks realizing authentic products [43].

In other words, engaging learners in PBL processes means leveraging their motivation by providing them with terrain to experience an educational path that is based on their interests and on significant learning goals in order to engage them in meaningful activities [58]. Among the principles that support PBL that have been identified by the most relevant researchers from the field [16,14,38,52,58,28] one can find the following ones:

- *Fostering learning through driving questions*: a good project should be ignited by a set of questions that serve the purpose of introducing learners to the right mindset needed to frame the issue and generate the right reasoning.
- *Set significant learning goals*: setting meaningful learning goals, based on real problems and coherent with the context lived by the learners is key.
- *Promote learning through projects*: projects should be strongly related to the broader curriculum and not something peripherical that may be not acknowledged as relevant or important.
- *Allocate the proper amount of time* to PBL to ensure that the learning goals are reached fully by the learners and that they would have the time to do it at their pace.
- *Promote a constructivist approach*: learners' active construction of knowledge is key. They should be encouraged in finding multiple solutions, exploring multiple strategies, and consolidating their learnings in a participatory process.
- *Situated learning*: learners should work on meaningful activities, in authentic environments where they are engaged in real-world tasks and are fostered in the development of practical skills and contextual understanding. It challenges traditional notions of decontextualized knowledge transmission, advocating for experiential and participatory learning methods.
- *Cultivate students' engagement* by making them ready and eager to learn and participate. This can be accomplished by involving the students and giving them more responsibilities since the early stage of the learning activity.
- *Scaffolding*: proposing the right project to the learners is particularly important to better intercept their motivation. A project should be something challenging enough to not be too easy and not be too hard for the learners. Tasks should be harder and harder as the students become more competent.
- *Encourage students' choices* by giving students more responsibility and control in the learning experience. This means having more space in deciding roles, tasks to work on, timing constraints, resources to use, and spaces.
- *Collaborative learning*: being able to work together, collaborate with peers, decide roles and individual tasks, and accomplish them is fundamental in PBL. A project is a task with very demanding objectives and collaboration between

peers is key to fully benefiting from the learning experience.

Some researchers refer to activities with characteristics similar to the one proposed in this contribution, with the term "competition-based learning" (CoBL). According to Kaye [32], which were among the firsts to propose this concept, the CoBL approach focuses mainly on proposing a competition (which can have lots of different denominations such as hackathons, code-a-thons, design projects) to the learners as a strategy to increase their motivation, their self-esteem and their learning achievements in accomplishing the task and in working together [8,42,39,62]. Along with these benefits, the use of competitions can also have negative effects on the learning process: it is difficult to assess the individual contribution within the groups, the attention toward the competition can result in a loss of interest in the regular educational proposal, some students can show hyper-competitiveness, stress, or performance anxiety [39,32].

2.2. Teaching AI at higher education levels

In recent years, AI has become widespread in many different applications, establishing new challenges to teaching AI at high education levels such as Universities [37]. It has been emphasized the importance of educating about artificial intelligence within formal education systems [30], not only from a purely didactic point of view but also from a citizenship education perspective [31] and the development of basic competencies for European citizenship [13]. To address these challenges, both the educator and the students must incorporate new techniques and skills into their competencies during the teaching period. Moreover, AI should be approached through non-traditional methods, such as games and competitions, and through practical experiences to improve learning. According to the "Learning by Doing" concept [19], nowadays it is highly preferred to merge the traditional (informative and passive) education model with an active and progressive model based on experiential and participatory learning processes to promote practical efficiency with awareness and critical thinking.

In this perspective, games and game competitions have played an important role in AI progress: besides providing stimulating research problems, games provide also benchmarks for comparing solutions and alternative approaches [12,60,23]. As a well-structured learning activity, game competitions can draw the attention and excitement of learners. Indeed, in the literature, competition in games has shown to have several benefits, including stimulating the interest of learners [2], motivating learners [49], and enhancing cooperation among learners [6]. Togelius [59] proposes a discussion of how to write up game-based AI competitions and what we can ultimately learn from them, based on the recent literature. A popular example is the University of Huelva (Spain) which has completely integrated the Google AI Challenge into its AI courses [7]. These experiments have been successful from many perspectives, resulting in an improvement in students' motivation and acquired knowledge. The ColorShapeLinks competition [24] is both a game and a framework that educators and students can extend and use to host their competitions. It has been successfully used for running internal competitions in AI classes, as well as for hosting an international AI competition at the IEEE Conference on Games. The authors of [21] design an escape room as a tool for teaching AI concepts to Air Force participants. Moreover, following the "learning by doing" approach to teach AI, other works [18,17,22,11] propose examples where traditional teaching is integrated with a practical activity (a game competition), that is relevant to the AI discipline and allows for active and playful participation of students.

With respect to our previous work [11], we conduct a larger and deeper study. In more details, we consider two different courses over 3 years, for a total of 6 iterations of the project, instead of 3 iterations over only one course. Moreover, while the mentioned work was based on a relatively small number of students (36), we perform a deeper and more structured analysis, based on the answers of 166 students. Finally, we have designed this project considering the students' feedback reported in those studies, such as the desire for a less-known game and a programming language-agnostic platform. In this perspective, we completely changed also the experience setting and the proposed game, as detailed in the following sections.

In the last years, several studies observed that competition during the learning process introduces positive effects, such as increasing learners' performance [53,44] and motivation [46,54]. However, it could also generate negative emotions, as students might feel anxiety over their performance in competition, often based on their different backgrounds and levels of knowledge. Recent works [57,27,45] focused on the design of educational computer-based competition environments with a set of features for improving the learning process (e.g., the combination of competition and collaboration [3], or the attention to the participants' knowledge background [10]). Based on these emerging aspects, in our work we analyzed the positive and negative effects of the proposed experience. In particular, we focused on the increasing learners' performance, motivation and competition, by conducting a structured analysis based on the students' feedbacks.

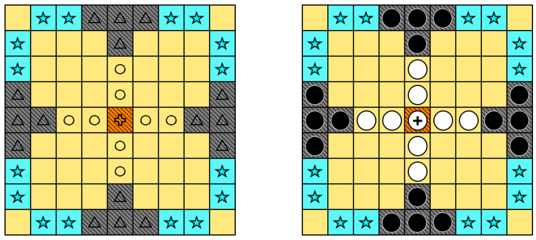

Fig. 1. Tablut board and initial setup.

3. Educational Contexts

The experience of integrating traditional, formal teaching with a practical activity (a game competition, in our case) was proposed as part of the "Fundamentals of Artificial Intelligence" subject, which was taught for a semester as part of a Master Degree in Computer Engineering [1] and a Master Degree in AI.[2]

Students of the Computer Engineering curriculum typically have a strong background in Computer Science or Engineering. In particular, the computer engineering-related courses comprise laboratory sessions, where students reinforce the acquired knowledge and apply it to practical experiences, for example by programming in languages such as C, Java, Python, and C#. Conversely, students of the AI curriculum often have a wider background that may include, for example, physics, statistics, or math.

Both courses are the first to address the topic of AI in the respective degree, and they introduce basic AI concepts such as planning and informed/uninformed complete/heuristic search strategies. Moreover, they lay the foundations for future courses that will introduce more advanced topics such as machine learning, scheduling, and optimization.

In more detail, the course introduces the fundamental principles and methods used in artificial intelligence to solve problems, with a special focus on the search in the state space, planning, knowledge representation and reasoning (First Order Logic and Description Logics), and on the methods for dealing with uncertain knowledge. In both the courses declarative programming languages are introduced, and in particular Prolog as a tool for knowledge representation and reasoning. The main prerequisite for students is a user-level knowledge of a high-level programming language, in order to successfully understand case studies and applications presented during the lessons. At the end of the course, the students know the main knowledge representation techniques and reasoning methods that underlie artificial intelligence problem solving, and they are able to develop simple solvers for artificial intelligence systems. Teaching methods are mainly based on traditional lectures (held in classrooms), and the courses include hands-on laboratory sessions and seminars on selected topics.

However, for three years, the COVID-19 pandemic forced schools to close their campuses and move didactic instruction online. The transition to online learning has raised several issues related to collaboration and the impact of online learning on students' course performance.

The competition presented in this work is introduced to the students during the course lessons, as a voluntary activity.

4. Method

Our objective is to present the results of research concerning the learning processes that occurred – and the related students' perceptions – during the application of Project-Based Learning (PBL) in an AI university course through practical experience. We do so by giving them the opportunity to develop a solution for a specific, well-defined, and adequately challenging problem: code an AI software player capable of playing the Tablut board game. Below, we describe our method starting from the description of the board game proposed (i.e., Tablut), then we describe the experiment setting, and finally we provide the implementation details.

4.1. Proposed Board Game: Tablut

Tablut is a strategy board game belonging to the family of Tafl games (sometimes called Hnefatafl

[1] `https://corsi.unibo.it/2cycle/ComputerEngineering`.
[2] `https://corsi.unibo.it/2cycle/artificial-intelligence`.

games), a group of Celtic and Nordic asymmetric board games designed for two players, which share similar rules. The exact rules of Tafl games are impossible to know, since little documentation has survived until the present day, and Tablut is probably the one for which most information is available. We designed the game engine mostly following the work of [1].

Board and Setup The game is played on a squared board of 9x9 cells by two players who control two different factions, Attackers (in black) and Defendants (in white). The initial setup of the game is illustrated in Figure 1. The central cell is called the castle (in orange, cross symbol), while on each board side there are 4 groups of 4 cells arranged with a t-shape that are called camps (in black, triangle symbol). The term citadel can be used to refer to either camps or the castle. The Attacker starts with 16 checkers, placed in the camps, while the Defendant controls one special checker, the King, and 8 other checkers. The King is placed in the Castle, while the other defendants are placed around it.

Rules The purpose of the attackers is to capture the King, while the defendants try to make it reach the edge of the board (in cyan, star symbol). The two players alternate turns during which they move a single checker, and lose immediately in case there are no moves they can make. If the same game state is reached twice, the game is declared a draw. A checker can be moved along a single straight line, by any number of cells, without passing over or ending in a cell occupied by another checker or a citadel, unless they started their movement in the same citadel. To capture an adversary checker, a player must "surround" it on two sides moving one of its own pieces. When the king is in the castle or adjacent to it, it is considered surrounded if there is an attacker on each of its sides. In any other case, a piece is considered surrounded if there are two enemy pieces on two opposite sides of its cell so that the three pieces are aligned horizontally or vertically.

Properties and motivation Following the *scaffolding* principle, we have chosen a game that is relatively simple, but also scarcely studied and addressed in the literature. Similarly to Nine Men's Morris (NMM) [11] and ColorShapeLinks (CSL) [24], this is a *complete-knowledge* and *deterministic* game. Indeed, at any moment in the game, the two players know everything about the state of the game and the consequences of any possible move. This makes it an ideal benchmark for an introductory AI course since it can be addressed with simple state-space search techniques. Conversely, games with hidden knowledge or random elements would typically require advanced AI methods to be addressed. Differently from NMM and CSL, the game is *asymmetric*: the two players have different starting positions, checkers, and goals. This characteristic distinguishes Tablut from most classic board games, hopefully making it more original to students. Moreover, the game is scarcely addressed in the literature, is currently *unsolved*, and its *complexity* has been compared to Othello and International Draughts [26]. This makes the challenge more stimulating for students since they can develop an original solution for a problem that has received little interest so far and that apparently cannot be solved by brute-force approaches. It also makes the experience closer to a real-life setting, thus respecting the *situating learning* principle.

4.2. Experience Setting

Guided by the principles of project-based learning, we structure the activity as follows.

Students are required to participate alone or in small teams of at most 4 people. We impose a limit on the number of participants because larger groups may reduce the involvement of each member compromising the efficacy of the experience. This activity may be more difficult for smaller teams, and working in groups may benefit *collaborative learning*. Nonetheless, we allow students to participate alone to value their independence and preferences. Students are required to communicate their participation to the teaching staff, for the sake of organization, but can withdraw at any moment without any consequence. Each student participating in the activity until the end is awarded a little bonus of about 7% on their final score on the subject.

The experience takes place in parallel with respect to the usual lessons. It is introduced to students about 4 weeks after the beginning of the course, when the strictly necessary background knowledge has already been provided. Students are then given between 6 to 8 weeks[3] to independently develop the software as part of their studies. During those weeks, the course covers many topics and techniques that may be useful for the experience. Even if no further time is dedicated to the experience during the course of the lessons, the teaching staff remains available for private meetings and supports students that ask for help.

Once all the software players have been delivered, the teaching staff runs a validation phase, where they

[3] The exact time depends on the schedule of the course.

discuss with the students regarding possible problems. Once all the players are functioning, the teaching staff runs a competition between the players. Finally, at the end of the semester, a lesson is dedicated to the results. Each team presents its work and discusses it with the teaching staff and the other students, then the results of the competition are announced.

Requirements Students are asked to develop software capable of playing a game of Tablut, which means that given a representation of the state of the board, it must be able to provide a move that is compliant with the rules. We *encourage students' choices* by imposing very few restrictions on the implementations, mostly regarding technical aspects (compatibility with our software and limited computational footprint), leaving students free to choose their solution based on their personal preferences.

We *promote a constructivist approach* by highlighting the importance of comparison between different methods and encouraging them to independently study topics that are not covered in the course, providing them with pointers to scientific literature and experts' seminars.

Competition Structure The competition is structured as a two-group tournament, with the best players of the two groups facing each other in a final set of matches. Within each group, the competition is structured as a round-robin tournament: each player must play against all the other players twice, once as the attacker and once as the defender.

With respect to the principles of PBL previously defined, we find our setting lacking in two aspects: the amount of time dedicated to the project and the cultivation of engagement. Concerning the former, even if the teaching staff dedicates a lot of resources to the project, there are time constraints imposed by the schedule of the semester. Extending the experience beyond the end of the course would encumber students with additional work to do during the exam session or in the next semester. We aim to cultivate engagement during the lessons by framing the topic presented in the course in the context of the challenge and by providing additional material, pointers, and seminars. But we do not assign them additional responsibilities or involve them in the run of the competition since we want to guarantee the fairness of the results.

4.3. Technical Implementation

We implement games as three processes: the two players and a server that acts as the game engine and the referee. The server is implemented in Java, while the communication with the game engine happens through JSON strings, a versatile format that allows communication between software implemented in different programming languages. The software is publicly available.[4]

Students are required to implement their players inside virtual machines with fixed characteristics that are provided by the teaching staff. The use of virtual machines allows forcing constraints on the computational resources that are available to all the players, creating the condition for a fair comparison. At the same time, the use of virtual machines and JSON allow students to develop their AI agent in the language they prefer, without favoring a specific background.

4.4. Evaluation

To assess the effects of the approach, we conduct a mixed-method evaluation [15], including both quantitative and qualitative methods.

Each semester we ask students to answer a questionnaire in an anonymous form and on a voluntary basis. To ensure student anonymity and address ethical considerations, we do not collect and do not process any personal data, including demographic information. The collection and management of the answers were performed in compliance with relevant laws and institutional guidelines.

The questionnaire is composed of 4 groups of 5 questions used to evaluate the students' perception of their knowledge of AI, their interest and motivation in the course, their personal skills, and the competitive aspect of the experience. During COVID-19 pandemic, we included a fifth group of questions specific The scores of the Likert scale range from 1, *strongly disagree*, to 5, *strongly agree*. The questionnaire ends with an open question asking for feedback, suggestions, and ideas phrased as "How could this experience be improved?".

For the quantitative analysis, we analyze the results computing the average score and the standard deviation related to each question. The qualitative analysis of the open question is conducted by two educational science researchers through inductive coding [9] using the ATLAS software.[5]

[4] `https://github.com/AGalassi/TablutCompetition`.

[5] https://atlasti.com/.

Table 1

Number of participants to the experience and to the questionnaire for each semester.

Year	**2019**		**2020**		**2021**	
Semester	I	II	I	II	I	II
Total participants	63	35	27	34	45	40
Collected answers	54	25	13	32	25	17

Table 2

Composition of the teams, considering only the students who answered the questionnaire.

Group members		**1**	**2**	**3**	**4**	**Tot**	**Avg**
2019	Semester I	2	14	12	26	54	3.1
	Semester II	2	6	11	6	25	2.8
2020	Semester I	0	3	10	0	13	2.8
	Semester II	5	8	8	11	32	2.8
2021	Semester I	1	8	11	5	25	2.8
	Semester II	1	3	11	2	17	2.8

5. Results

The experience has been held for 3 years consecutively (2019-2021), for a total of 6 semesters. In total, 244 students have participated, divided into 85 teams, for an average of 14 teams competing during each semester. To assess the effects of the approach, each semester we have asked the students to answer a questionnaire in an anonymous form and on a voluntary basis. Our results are based on a total of 166 answers collected out of 244 participants, which amount to about 70% of the total number of participants. In Table 1 we show the number of students who participated to the experience and the number of students who answered the questionnaire for each semester. Table 2 details the composition of the teams, considering only the students who answered the questionnaire.

Throughout the rest of the paper, we refer to percentages exclusively for the students who responded to the questionnaire. Moreover, to clearly define the sample of collected answers, we also provide the information related to the numerical composition (average) of the competing teams. Note that we provide information only related to the teams that answer to the questionnaire.

5.1. Method Evaluation

Table 3 reports the questionnaire result while Figure 2 provides a graphical visualization. Concerning the efficacy of the experience in teaching AI and improving strictly related skills, the results are satisfactory. On average, the students agree that this initiative is beneficial both for consolidating concepts learned during the course (A1) and acquiring new knowledge on the topic (A2). The experience has a positive impact also on the ability to problem-solving (A3, A5), while it is not particularly beneficial for learning concepts related to programming languages (A4). Additionally, we have personally observed that many students have preferred to focus on AI techniques not covered in the course, in some cases to the detriment of the performance in the challenge.

The experience has slightly increased the students' appreciation of the course (B1, B2), from 3.93 to 4.22, and the general assessment regarding the whole experience is positive (B5).

The experience is considered beneficial also for the development of personal skills (C1-C5) such as work organization and the ability to work in teams, with all the questions receiving a score above 4 and a standard deviation around 1.

While structuring the experience as a competition positively influences the students' motivation and promotes collaboration within the teams (D1, D3), it does not seem to affect the collaboration between different teams (D2). Nonetheless, the prizes do not have an impact on participation in the competition (D4, D5), in particular, winning the first prize does not seem to be a strong motivating factor. It is also important to note that for students that already obtain full marks during the exam, the bonus points offered as a prize do not have any value.

In general, we can observe a standard deviation lower than 1 in most of the questions. This means that most students do not diverge from the average score of more than 1 level on the Likert scale, and therefore indicates a general agreement between students on their answers. The questions with the highest standard deviation are the ones concerning the relevance of the competitive aspects.

We conducted a t-test to verify the significance of the results. For almost all the questions in group A-D we obtained a p-value lower than 0.001, validating our results. The only exception is question D2, for which we obtained a p-value of 0.106, which we do not consider significant for our findings.

Table 3

Answers to the questionnaire. For each question, we report the average score (AVG), the standard deviation (SD), and whether the p-value obtained through the t-test is lower than the conventional threshold $\alpha = 0.05$. Scores are expressed on a Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

ID	Question	AVG	SD	$p < 0.05$
	Knowledge			
A1	The experience enables the consolidation of theoretical concepts on AI	4.34	±0.73	yes
A2	The experience allows new concepts on AI to be acquired	4.15	±0.99	yes
A3	The experience allows to discover new ways to solve problems	4.29	±0.78	yes
A4	The experience allows new concepts on language programming to be acquired	3.63	±1.08	yes
A5	My ability to apply knowledge in practical and real problems after the challenge is positive	4.14	±0.80	yes
	Interest and Motivation			
B1	My general assessment for the course before the experience is positive	3.93	±0.87	yes
B2	My general assessment for the course after the experience is positive	4.22	±0.77	yes
B3	The result obtained in the challenge influences learning on AI	3.44	±1.22	yes
B4	The result obtained in the challenge influences interest and motivation	4.07	±1.02	yes
B5	My general assessment for this practice/experience is positive	4.28	±0.82	yes
	Personal and Practical Skills			
C1	The value of sharing information before the challenge is positive	4.02	±0.89	yes
C2	The value of sharing information after the challenge is positive	4.22	±0.79	yes
C3	The experience serves to better understand personal skills	4.02	±1.02	yes
C4	The experience allows knowledge on work organization to be acquired	4.19	±0.94	yes
C5	The experience allows knowledge on cooperation and teamwork to be acquired	4.30	±0.95	yes
	Competition			
D1	Competing in a challenge improves team collaboration	4.23	±0.89	yes
D2	Competing in a challenge improves collaboration with other teams	2.85	±1.19	no
D3	Competing in a challenge promotes motivation and interest	4.46	±0.83	yes
D4	Participation in the competition is strongly linked to the winning of the first prize	2.45	±1.21	yes
D5	Participation in the competition is strongly linked to the winning of the participation prize	3.32	±1.22	yes
	COVID-19 Impact			
E1	The COVID-19 safety measures have increased the difficulty of team coordination	2.61	±1.38	yes
E2	The COVID-19 safety measures have increased the difficulty of daily work schedule	2.66	±1.37	yes
E3	The COVID-19 safety measures have increased the difficulty of concentration	3.03	±1.43	no
E4	The COVID-19 safety measures have increased the difficulty of communication with professors	2.84	±1.20	no
E5	The COVID-19 safety measures have increased the difficulty of communication with other students	3.11	±1.50	no

5.2. Impact of COVID-19 and Remote Lectures

With the advent of the COVID-19 pandemic, the competition was forced to be held remotely. Thus, both the instructions for the competition and the collaboration among team members were forced to be made remotely. In this analysis, we focused on the possible repercussion of such drastic changes in the learning process of the students involved in the challenge. To this end, we compared the answers provided by the participants pre-pandemic with the ones collected during the outbreak. To better assess the effect of COVID-19 on the participants we included a set of questions explicitly aimed at capturing the opinions and perceptions of the students.

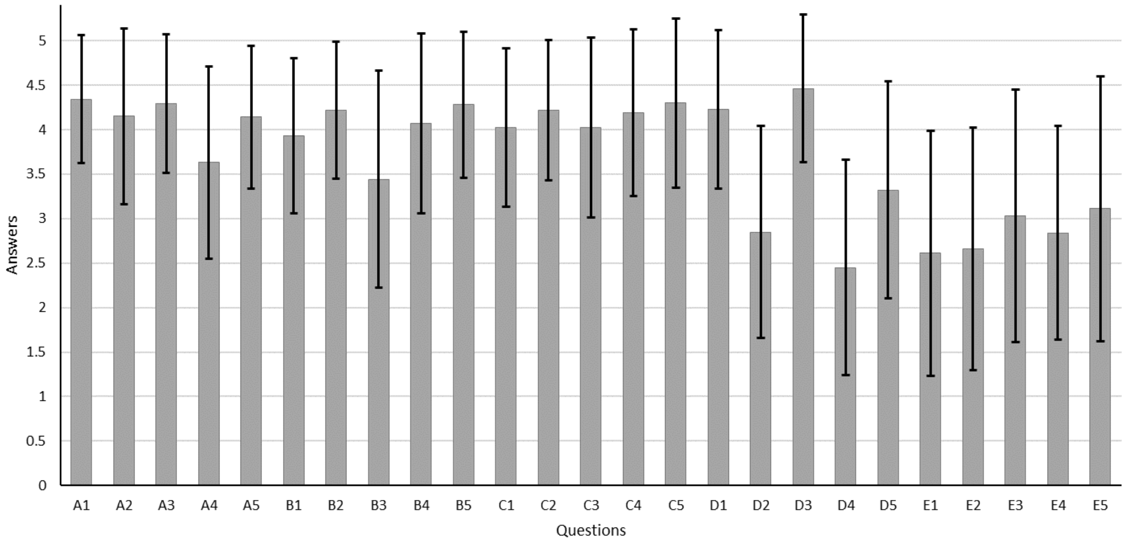

Fig. 2. Visualization of answers to the questionnaire. For each question (x-axis), we report the average score (grey bins) and the standard deviation (error bars).

Table 4

Comparison between answers obtained before and during COVID-19.

Q	Before COVID-19 AVG ± STD	During COVID-19 AVG ± STD	Diff. in AVG	p-value
A1	4.40 ± 0.67	4.28 ± 0.77	-0.11	0.251
A2	4.15 ± 0.88	4.15 ± 1.08	-0.01	0.862
A3	4.29 ± 0.84	4.28 ± 0.74	-0.01	0.821
A4	3.77 ± 1.01	3.50 ± 1.13	-0.27	0.096
A5	4.22 ± 0.80	4.08 ± 0.81	-0.14	0.204
B1	3.96 ± 0.81	3.91 ± 0.92	-0.05	0.562
B2	4.27 ± 0.73	4.18 ± 0.81	-0.09	0.377
B3	3.50 ± 1.13	3.39 ± 1.31	-0.11	0.425
B4	4.09 ± 0.94	4.05 ± 1.08	-0.04	0.672
B5	4.23 ± 0.85	4.32 ± 0.80	+0.09	0.587
C1	4.05 ± 0.84	3.99 ± 0.94	-0.06	0.533
C2	4.17 ± 0.76	4.26 ± 0.82	+0.09	0.540
C3	4.15 ± 0.97	3.90 ± 1.05	-0.26	0.105
C4	4.40 ± 0.76	4.00 ± 1.04	-0.40	0.003
C5	4.45 ± 0.82	4.16 ± 1.04	-0.29	0.035
D1	4.24 ± 0.89	4.23 ± 0.91	-0.02	0.803
D2	3.05 ± 1.15	2.67 ± 1.21	-0.38	0.038
D3	4.49 ± 0.77	4.44 ± 0.88	-0.04	0.658
D4	2.31 ± 1.13	2.58 ± 1.27	+0.27	0.263
D5	3.14 ± 1.18	3.48 ± 1.24	+0.34	0.120

As can be seen in Table 4, the answers to the questionnaire revealed no significant impact of the epidemic on the experience. In particular, the mean and the standard deviation on the responses between the pre-pandemic and the emergency time are almost invariant.

We conducted a t-test to compare the answers obtained before COVID-19 and during COVID-19. For most answers, we obtained a p-value greater than 0.05, indicating that the difference between the two distributions is not statistically meaningful. For three questions, C4, C5, and D2, we obtained a p-value lower than 0.05. These results confirm our claim that the pandemic did not have a significant impact on the overall experience but also point out that logistical and social aspects were negatively influenced.

Regarding the questions directly measuring the impact of COVID-19 on the workflow of the participants (E1-E5), we detect, on average, a mild effect on the overall experience. Nevertheless, we can observe a significant variance in the answer provided, likely pointing to some students who had a negative experience. However, conducting the t-test for these 5 questions, we obtained a corresponding p-value of 0.010, 0.022, 0.823, 0.218, 0.478. This suggests that we can only consider E1 and E2 as statistically significant and that the other questions should be considered only as qualitative results.

5.3. Analysis of the Open Question Answers

With the purpose of capturing additional critical aspects of the experience, we process the answers to the open question and analyze them based on an inductive method, showing the results in Table 5. This anal-

Table 5

Feedback of open question grouped in categories. For each category, we report also the number of students that mentioned it and their percentage on the total number of answers.

Macro Issues	#	%	Category	#	%
Organizational	27	16%	Timing and deadlines	18	11%
			Modalities for presenting	8	5%
			Opportunity to see live games	5	3%
Didactical	29	17%	Task's explanation	17	10%
			Theoretical insights	9	5%
			Laboratories	6	4%
			Necessary prerequisites (coding)	4	2%
Motivational	25	15%	Dialogue between groups	12	7%
			Reward	9	5%
			Dialogue with professors	6	4%
			Competition aspect	1	1%
Task-related	28	17%	Technological aspects (e.g., server code)	22	13%
			Game unbalance	8	5%
			Size of groups	2	1%
Appreciation Feedback	17	10%			

ysis was implemented separately by two different educational science researchers to ensure a more plural and objective approach, which then converged on an agreed schema based on two hierarchical levels. For the final step, a computer science researcher has helped to disambiguate some answers. We report percentages over the total number of students who provide an answer to the questionnaire. It is important to remark that several students did not provide an answer to the open question. Other students instead have addressed several items, and therefore their answer is counted in multiple categories. All four macro-categories received a similar number of comments, from about 15% to 17% of participants in the questionnaire.

For what concerns the organization, the most problematic aspect seems to be the timing and the deadlines (11%). Students would prefer to have more time to work on the challenge and some of them suggest moving the starting date to the end of the lessons: "The challenge should be run after [...] the end of the course or, at least, start after we have seen all the topics in the course". The presentation mode of the students' projects could also be improved (5%), and a few would prefer to see live games (3%), possibly also live tournaments with rankings in a public server.

17% of the students report critical issues related to didactic aspects. Students suggest improving the explanation of the assignment (10%), providing a more detailed description in advance, including indications both concerning AI topics ("provide more information during the lessons about the min-max algorithm"), and the experience itself. Other improvements suggested by the students are to provide more theoretical insights (5%) since most students "start from the beginning"; to include more laboratory moments and provide activities that stimulate cooperative learning "by interacting teams, exchanging opinions on problem-solving" (4%). Finally, a few of them (2%) ask to specify coding skill requirements better from the start of the challenge since some of them may lack a strong background in computer science.

Regarding motivation, students point out the need to increase the moments of confrontation among peers (7%) and with teachers (4%). Some of them propose intermediate confrontation days where they can also try out their players and test them. About 5% of students believe that the recognition for participation is not adequate and proportionate to the effort required and propose to assign more credits. Only one student reports that competition is "a double-edged sword for the student who has much more to lose than to gain".

The relative majority of the students' feedback (13%) concerns technological aspects, such as the code of the server or the use of virtual machines for delivery. In particular, they observed that the method used by Java to process and communicate JSON strings is not directly compatible with other languages, requiring ad-hoc solutions. During the first period of Covid-19, a small group of students complained about the use of virtual machines, since they were not provided with a fast internet connection in their homes, resulting in long downloading and uploading time of the virtual machine. In the same macro-category, another shared complaint was the inherent unbalance of the game (5%) since is “too convenient for the black player”.

Finally, we received positive feedback (10%) regarding the whole experience. For example: “so far the most interesting university-level project I have participated in” because “having to work on a fairly unknown game like Tablut [...] gave the opportunity to start from the beginning”.

6. Discussion

The answers obtained through the questionnaire are satisfactory and generally provide affirmative answers to all our research questions. The students agree that the experience is beneficial to the acquisition of knowledge related to AI but also of more general soft skills. The experience is generally appreciated and motivates the students.

Concerning the impact of the competitive aspect of the experience, we can observe that it yielded a positive effect on students’ engagement. Moreover, we speculate that the lack of interest in the prizes and the results may indicate a general absence of negative factors, such as stress and anxiety.

One of the main limitations of this study is the use of a self-assessment questionnaire. While this approach may correctly measure the engagement level of the students, it is not ideal to assess the quality of the learning process. As an alternative, we could compare the exam’s grading between the group of students who took part in the challenge and those who did not. However, since the experience is on a voluntary base, we would not be able to capture clear causal relations but only potential correlations.

Regarding the implementation of the PBL principles, students’ answers have highlighted that the time allocated may not be enough. Unfortunately, anticipating the start of the experience before providing the necessary information about the course, or delaying its end after the teaching period, is an unfeasible solution. While we obtained good results regarding interest and engagement, students expressed the desire for more lessons dedicated to problem discussion with the teaching staff, cooperative learning between different teams, and laboratory lessons.

The latter is likely easier to address by scheduling dedicated lessons for sharing and discussing possible solutions during the course. This would also improve collaborative learning among different teams, an aspect currently not encouraged enough. A more impactful solution may be to separate the experience from the AI course and structure it as a proper curricular activity. This would allow us to schedule it after the course and to run it for an entire semester, rewarding participants with curricular credits, and dedicating more lessons to the discussion of the problem between students and the teaching staff. Another solution could be to make the competition more flexible and dynamic by allowing teams to register and deliver their software at any time during the academic year. However, this would make it harder to organize a moment to share and discuss their work.

Concerning the game, we observed that the attacking player is slightly advantaged (48% of games won against 41% of the adversary). Nevertheless, this is a common trait among board games and the unbalance in Tablut is comparable to the one observed in many other popular board games, such as chess [56].

Finally, we observe that participation in the challenge was not affected by the advent of the COVID-19 pandemic, with fewer exceptions in which a restricted number of participants might have experienced more discomfort. Thus, we claim that the design of the experience is robust enough to remain effective also in a remote learning setting.

7. Conclusion

This research project proposes the study of the application of Project-Based learning in a university course in Artificial Intelligence. The experience is designed as an activity that takes place during the teaching period. We framed the experience as a challenge in which the students develop an AI agent for the board game Tablut. We assessed the learning experience of the students through a self-assessment questionnaire, which resulted in 166 answers on which we performed our analysis. The results point to a positive involvement of the participant, which showed an increased level of motivation and investment in the course, underlying also the development of personal skills.

Our study confirms the general efficacy of PBL, which we implemented in most of its aspects. Nonetheless, the survey highlights some critical point of the experience that need more attention, such as the time allocated to the activity, the collaboration among different teams, and the opportunity to discuss with the teaching staff. For what concern the competitive aspect, we obtained a positive response from the participants and did not observe the development of negative aspects such as hyper-competitiveness or performance anxiety.

We believe that curricularizing the experience would have a greatly positive impact. This would include dedicated lesson hours in the laboratory, time and spaces for discussion, and recognizing formative credits for it. Moreover, further collaboration with researchers and players from the educational sciences could be beneficial and provide additional perspectives. The integration of non-traditional activities as part of a university curriculum is typically a long process, especially when it requires the collaboration of experts from different fields. We hope that our study will be useful in facilitating this process in the future.

Finally, we also complemented the analysis by taking into account the altered environmental conditions due to the COVID-19 outbreak. Our assessment does not show significant changes in the experience except for a smaller group of participants.

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Conflict of Interest

The authors declare no conflict of interest.

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