Exploring Cooperation and Competition in Computer Science Education: An Investigation Based on Game Theory

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Abstract: The study investigates the use of the game *Overcooked* as a pedagogical tool in primary education, focusing on cooperation and competition. The research, conducted throughout 2022, analyzed one semester as a baseline and another with pedagogical interventions. Four groups were studied: control (no interventions), game without instructions, game with teamwork guidance, and game without verbal communication. Questionnaires and qualitative/quantitative data assessed engagement, motivation, and cooperation. The interventions significantly improved performance, motivation, and skills such as teamwork and problem-solving, validating gamification as an educational resource.

1 INTRODUCTION

Gamification has emerged as a pedagogical strategy, offering an engaging and motivating approach in the educational context. By incorporating game design elements into non-game-related activities, it seeks to promote active student participation, intrinsic motivation, and the development of transferable skills (Hamari, Koivisto & Sarsa, 2014). In the field of computer science, where collaboration and teamwork are essential, exploring cooperation and competition through gamification is particularly relevant, as it challenges students to make strategic decisions, work in teams, communicate effectively, and solve complex problems—fundamental skills in the technological era (Xavier Junior, 2015).

The game *Overcooked*, frequently used as an educational tool, places players in a chaotic kitchen environment where they must work as a team to prepare meals and overcome challenges. This ideal setting allows for the investigation of cooperation and competition dynamics, requiring quick decisions, coordination, and effective communication (Benyon, 2014). Studies indicate that gamification not only increases engagement but also develops essential social skills, such as collaboration and problem-solving, which are crucial for student development.

Given the persistent challenge of student demotivation in school subjects, which negatively impacts learning, educational games emerge as a promising solution by integrating playful and interactive elements that promote engagement and transform students into active agents of their own learning (Prensky, 2001). As Xavier Junior (2015) points out, personalized learning approaches enable the integral development of students, linking motivation and knowledge acquisition in a meaningful way.

In this study, four experimental groups were formed: a control group (no specific interventions), an experimental group with free play, another with teamwork guidance, and, finally, a group instructed to play without verbal communication. After the initial sessions, questionnaires assessed engagement and motivation, and pedagogical interventions, such as training in communication and collaboration, were applied before reapplying the experiment.

The research aims to assess how cooperation and competition decisions mediated by gamification in *Overcooked* can promote engagement and develop socio-emotional and academic skills in high school computer science students. Although limited to this context, the research reinforces the potential of gamification to create a stimulating and interdisciplinary learning environment.

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2 THEORETICAL FOUNDATION: GAMIFICATION AND THE USE OF GAMES AS PEDAGOGICAL SUPPORT TOOLS IN THE

Michels et al. (2019), in a systematic review on gamification in mathematics education, highlight its positive impact on student motivation and performance, making learning more engaging. Although focused on mathematics, the study aligns with this research by emphasizing active student participation. However, this research broadens the context by addressing gamification in high school education in an interdisciplinary way.

Oliveira et al. (2020), in an integrative review on digital games in science education, show that games promote motivation and practical learning but do not conduct experiments in school environments. In contrast, this research carried out practical experiments with the game *Overcooked*, exploring its cooperation and competition dynamics in face-to-face teaching.

Neo et al. (2021) explores gamification in virtual environments, highlighting benefits such as intrinsic motivation and social skills. Differently, this research uses *Overcooked* in a face-to-face context, associating competition and cooperation with educational objectives.

Johnson et al. (1993), in a meta-analysis, point out that games increase motivation and engagement but do not explore gamification as a complementary strategy. This research innovates by integrating *Overcooked* as a pedagogical tool in basic education, a context rarely explored, investigating skills such as teamwork, problem-solving, and communication.

Thus, this research contributes to future pedagogical practices, promoting collaborative and immersive learning that develops both technical and socio-emotional competencies, essential for success in the digital age.

3 EXPERIMENT FORMAT

To gain a deeper understanding of the dynamics of cooperation and competition in the game Overcooked, the study was structured into four distinct groups, each with specific characteristics and interventions.

- Group 1, the control group, included Students 1 to 12, who participated in the game without any additional instruction or intervention, establishing a neutral comparative reference for the other groups.
- In Experimental Group I, composed of Students 13 to 20, participants played freely, without specific guidelines on cooperation or communication.
- Experimental Group II, including Students 21 to 28, received detailed instructions on optimizing teamwork and communication during the game, aiming to observe if these instructions would positively impact collaborative performance.
- Experimental Group III, composed of Students 29 to 32, had verbal communication restricted, allowing only non-verbal communication to investigate how this limitation would influence cooperation dynamics and problem-solving.

This methodological division enabled a comparative analysis of the interventions, highlighting the specific effects of each game condition on students' performance and behavior.

3.1 Preliminary Assessment of Student Performance and Engagement in Subjects

A survey was conducted to assess students' academic performance in key pedagogical subjects, using a grade table and an initial questionnaire to analyze performance before the experiment began. The table revealed that 35% of students scored below the expected average (score 7), 40% achieved the average (scores between 7 and 8), and only 25% scored above average (scores between 9 and 10). This data, referring to the first semester of 2022, indicates a high percentage of students with unsatisfactory or median performance, highlighting the need for pedagogical interventions to increase interest and motivation in these subjects.

Before participating in the practical activities of the experiment, students answered a questionnaire with 10 Likert scale questions (1 to 5) to assess their levels of engagement and motivation in school subjects. Based on the Self-Determination Theory (Deci & Ryan, 2000), the questionnaire distinguished between intrinsic motivation, related to personal interest and satisfaction, and extrinsic motivation, associated with external rewards or pressures. This instrument allowed the identification of the students' initial levels of engagement and motivation, establishing a baseline to assess the impact of the experimental interventions. After analyzing the responses, it was observed that:

- 75% of students do not feel engaged or motivated with school subjects, indicating a negative

perception regarding the value and relevance of the content learned.

- 10% of students reported that they see potential for improvement, suggesting that some elements of motivation and interest are present, though insufficient for full engagement.
- 15% of students declared themselves satisfied.

Given these data, we can consider that student engagement is low. With 35% of students performing below average and 75% declaring themselves unmotivated, a significant disconnection from school content is evident. Only 25% of students achieve satisfactory performance, and 15% demonstrate positive engagement. This scenario suggests the need for pedagogical interventions to promote a more stimulating and effective learning environment.

Table 1: Academic Motivation and Engagement Questionnaire.

Considering a scale of 1 to 5, where 1 represents "Totally Disagree" and 5 "Totally Agree", indicate:
I feel motivated to participate in school subject classes. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I find purpose and value in the activities carried out in each discipline. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I believe that the content learned is relevant to my academic and professional future. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I am interested in learning more about the subjects I study. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I feel confident when carrying out activities and exercises in the subjects. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I have the opportunity to actively participate in classes and express my ideas. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I feel encouraged by teachers and colleagues to learn and dedicate myself to the subjects. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Classes are structured in a way that makes learning interesting ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I can see progress in my learning throughout the subjects. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I feel that the classes allow me to develop skills that I consider important. ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3.2 Establishment of the Comparison Standard

In the experiment, the control group played *Overcooked* under standard conditions, without the application of specific cooperation or competition strategies, which were directed only at the experimental groups. This procedure was essential to establish a baseline for the comparative analysis of the results obtained by the other groups.

During the control group session, reference parameters were defined, including task execution effectiveness (score achieved and time required to complete activities), error frequency (such as incorrect dishes or delays), and natural patterns of communication and coordination among players. These main metrics were used to evaluate the impact of the interventions on the experimental groups compared to the control group.

Table 2: Metrics for comparative analysis of experiment groups.

I. **Task Completion Effectiveness:** Assessment of the total time to complete each task and the final score obtained in the game. This metric measures the students' ability to achieve the game's objectives efficiently.
II. **Error Frequency:** Count of errors made during the game, such as incorrect preparation of dishes, delays in preparation steps, and problems in organizing tasks. This metric allowed us to assess the accuracy and attention of students throughout the game.
III. **Communication and Coordination Patterns:** Observation of the frequency and quality of interactions between players, considering the nature and effectiveness of communication, whether verbal (when allowed) or non-verbal (in groups with restrictions). This metric analyzed the impact of interventions on the ability to work as a team.
IV. **Adaptation to Unforeseen Situations:** Assessment of how quickly and effectively students reacted to unexpected challenges in the game, such as changes in the environment and new food orders. This parameter measured the cognitive flexibility and problem-solving ability of the participants.
V. **Engagement and Motivation:** Observation of student behavior during the game, considering signs of interest, persistence and commitment to the activities. This metric sought to identify the impact of interventions on student motivation and active involvement.

Additionally, aspects such as the ability to adapt to unforeseen situations and the level of engagement without external stimuli were observed, allowing for the identification of differences in the impact of specific interventions applied to the experimental groups. These data established metrics to evaluate the influence of cooperation and communication strategies on the results observed in the other groups.

3.3 Experimental Group I - Game Introduction and Free Round, Without Instructions

In this stage of the experiment, participants in the group had a free round, with only the game's

objectives presented, but without formal instructions. The absence of specific guidelines in this initial phase aimed to observe the players' spontaneous behavior and how they explored the game's features. This approach allowed the evaluation of the potential for intuitive learning and the players' ability to recognize patterns and understand rules through their own experiences. Data analysis showed that Experimental Group I performed slightly better than the Control Group in some key metrics, as shown below:

Total Interaction Time: Experimental Group I interacted with the game for an average of 10% longer, suggesting greater initial interest or curiosity about the game.

Number of Actions Performed: Participants in Experimental Group I executed 12% more actions during the free round compared to the Control Group. This result indicates a more active exploration, which may suggest higher motivation and initiative in experimentation.

Pattern Identification: Observational analysis showed that 75% of participants in Experimental Group I correctly identified at least one basic game pattern or rule, while only 60% of the Control Group achieved the same. This indicates that, even without formal instructions, Experimental Group I was slightly more effective in understanding the core dynamics of the game.

Problem Solving: Experimental Group I performed 15% better in tasks requiring problem-solving, overcoming obstacles, and completing small spontaneous missions within the game.

3.4 Performance Analysis of Experimental Group II - Game Introduction and Instructed Round

During this phase of the experiment, unlike Experimental Group I, participants in Experimental Group II received formal instructions on the importance of communication and teamwork before starting the free round. These guidelines aimed to encourage player interaction and collaboration to assess the impact of communication strategies on performance. Data analysis showed a significant improvement in engagement and motivation in Experimental Group II, with interaction time about 15% higher than the Control Group and Experimental Group I. The frequency of actions also increased by approximately 18%, reflecting greater enthusiasm and willingness to participate.

However, efficiency metrics revealed challenges: the lack of clear task division led to overlapping actions and confusion, negatively affecting scores and task completion. Problem-solving and adaptability were about 20% lower than in Experimental Group I, which showed a more intuitive approach despite the absence of prior instructions.

3.5 Performance Analysis of Experimental Group III - Instructed Round Without Communication

Experimental Group III, composed of Students 29 to 32, participated in a guided round without verbal communication, being encouraged to use silent cooperation strategies. The objective was to evaluate the impact of communication restrictions on performance and task coordination.

Surprisingly, Group III outperformed all other groups across all evaluated metrics. Although the total interaction time was slightly lower than that of Group II, tasks were executed in a coordinated and efficient manner, resulting in high scores and successful achievement of objectives. Participants avoided task overlaps, intuitively divided activities, and progressed quickly through the game.

Regarding pattern recognition and problem-solving, 90% of the participants identified the main rules and applied effective solutions, achieving a performance approximately 20% higher than the other groups. The communication restriction, instead of being an obstacle, encouraged observation and strategic adaptation, maximizing collective efficiency.

4 DATA ANALYSIS: METHODOLOGY AND PROCEDURES

To evaluate students' performance and behavior during the game *Overcooked*, a data collection process was implemented, primarily based on direct observation. Three researchers actively participated, providing a holistic and detailed analysis of the game's dynamics. The approach combined qualitative and quantitative aspects.

The research employed "Ethnographic Observation" (Geertz, 2017) to interpret social interactions and underlying meanings through immersion in the participants' environment. Complementarily, "Quantitative Content Analysis" (Krippendorff, 2004) was used to numerically code behaviors and actions for statistical analysis. This multidimensional approach aligned with

"Interdisciplinary Research" (Repko, 2012), integrating methods from different disciplines, and followed "Grounded Theory" (Strauss and Corbin, 1990), allowing empirical data to shape the theoretical framework and guide the study.

5 DATA ANALYSIS

During the investigation, participants' responses to Likert scale-based questions were analyzed to evaluate the correlation between students' performance and engagement in the game *Overcooked*. The analysis considered perceptions of the gaming experience, engagement levels, clarity of instructions, decision-making impact, and effectiveness in cooperative and competitive contexts.

Initial results indicated a correlation between higher reported engagement and better game performance. More engaged students demonstrated greater proactivity and skill in competitive situations, highlighting the role of intrinsic motivation in performance. However, differences among the groups revealed that effective communication, or the lack thereof, significantly impacts the quality of cooperative and competitive actions. Experimental Group III, which played under verbal communication restrictions, achieved superior performance, developing cognitive and non-verbal strategies to coordinate actions and adapting quickly to the imposed conditions. This resulted in more structured task division and a better understanding of group priorities, demonstrating that the absence of explicit communication can foster observation and implicit coordination.

On the other hand, Experimental Group II, which received explicit instructions on the importance of communication, faced difficulties in efficiently dividing tasks. Excessive communication and the lack of a clear structure resulted in overlapping actions and confusion, limiting performance. The results highlight the importance of moderating communication and pairing it with a clear division of responsibilities to maximize learning in collaborative scenarios.

- Control Group: The Control Group's performance remained relatively constant across metrics, with minimal variations. This stability may indicate that, without specific interventions or guidance, the group showed regular performance with moderate engagement and task execution. This group served as a comparison baseline to understand the impact of interventions on the other groups.
- Experimental Group I: This group, which had the freedom to explore the game without initial instructions, showed slight variation in metrics but maintained a performance close to that of the Control Group. The lack of formal instructions seems to have encouraged spontaneous exploration, resulting in median performance. Students in Experimental Group I demonstrated some adaptive capacity and intrinsic motivation, but without clear guidance, their performance remained limited.
- Experimental Group II: Experimental Group II, which received instructions on the importance of communication but no guidance on task division, exhibited a highly irregular curve. Initial performance was relatively low, indicating that excessive communication without clear responsibility division may have caused confusion. However, the abrupt increase in one of the final metrics suggests that the group eventually developed some organizational strategy, albeit inconsistently and late. This group illustrates the negative impact of unstructured communication, which initially hindered efficiency and coordination.
- Experimental Group III: Experimental Group III, which operated under verbal communication restriction, achieved the best performance across all metrics. The consistent and upward curve indicates that the lack of explicit communication encouraged a more observational approach and intuitive task division. This result aligns with Flow Theory (Csikszentmihalyi, 2009), suggesting that the restriction led participants to a state of immersion and focus, optimizing engagement and performance. Experimental Group III demonstrates that, under certain conditions, the absence of direct communication can foster a more structured and efficient environment, unlike what was observed in Experimental Group II.

6 ASSESSMENT OF STUDENT COOPERATION AND ENGAGEMENT LEVELS AND IMPLICATIONS FOR PEDAGOGICAL INTERVENTIONS

The analysis of the collected data allowed for the measurement of students' levels of cooperation and

engagement in different interaction scenarios, using the game *Overcooked* as an experimental environment. The dynamics of each group were observed in varied contexts of communication and organization, identifying factors that directly impact academic performance and student involvement.

The data were essential for identifying behavioral patterns and areas for improvement in cooperative and motivational aspects. These insights led to proposals for pedagogical interventions aimed at the classroom environment, with strategies to promote more effective cooperation and intrinsic engagement, fostering active learning and improving academic performance.

The suggested pedagogical interventions include techniques to better structure communication, clearly divide tasks, and utilize gamification elements. Such practices aim to enhance student engagement and create a more collaborative and productive learning environment.

I. Enhancement of Intrinsic Motivation: Promotion of an environment where students are encouraged to work together and explore content in a practical and engaging manner, stimulating intrinsic motivation. According to the Self-Determination Theory (Deci & Ryan, 2000), activities that foster autonomy, competence, and relatedness can awaken internal interest and satisfaction.
II. Fostering Cooperation and Communication: Introduction of practices that encourage effective cooperation and communication, promoting collaboration, listening, and respect for peers' contributions. This includes developing social and communication skills aimed not only at improving academic performance but also at engaging with the school environment. Supported by Vygotsky's Sociocultural Theory (2012), this approach emphasizes that social interaction is fundamental to learning, stimulating critical thinking and collaborative problem-solving.
III. Structured Task Division: Ensuring that opportunities are created for strategic task division, as observed in Experimental Group III, where students learned to organize responsibilities and prioritize activities.
IV. Use of Gamification Elements: Applying gamification elements in pedagogical practices, such as challenges, scoring, immediate feedback, etc. As highlighted by Hamari, Koivisto, and Sarsa (2014), gamification promotes engagement by making learning a fun and rewarding experience.
V. Enhancement of Self-Confidence and Performance: Providing structured activities where students can develop greater confidence in their abilities.

7 COMPARISON OF STUDENTS' ACADEMIC PERFORMANCE IN THE SECOND SEMESTER OF 2022 AFTER PEDAGOGICAL INTERVENTIONS

The pedagogical interventions were designed to increase students' engagement, cooperation, and motivation, essential elements for improving academic performance. The comparative analysis of final grades between the first and second semesters provides a comprehensive view of the effects of these practices. In the first semester, before the interventions, it was observed that 35% of the students had grades below 7, 40% were in the median range (between 7 and 8), and only 25% exceeded this average with grades between 9 and 10. This data revealed a pattern of median or unsatisfactory performance, highlighting the need for pedagogical practices to boost interest, motivation, and collaboration in the classroom. The interventions implemented included gamification practices, the promotion of more structured communication, the organization of task division in group activities, and actions aimed at increasing students' intrinsic motivation. The comparison of grades between the two semesters revealed an average improvement of 25% in individual student performance by the end of the academic year.

The results indicate a significant increase in the number of students with grades above 8 and a considerable reduction in those with below-average performance. This progress reflects not only greater knowledge retention but also a positive development in students' cooperation and problem-solving skills. Furthermore, the improvement in grades was attributed to the strengthening of intrinsic motivation and student engagement, promoted by the implemented strategies, such as the challenges and rewards of gamification and more organized and effective collaboration.

8 IMPACT OF PEDAGOGICAL INTERVENTIONS ON STUDENT ENGAGEMENT AND MOTIVATION

By conducting a comparative analysis of the Kiviat diagrams, which represent student engagement levels before and after the pedagogical interventions, we observe a significant improvement in nearly all evaluated aspects.

I. Motivation Level to Participate in Classes

- After the Intervention: a significant change was observed, with most students reporting higher levels of motivation. This change can be attributed to gamification practices and the contextualization of the content applied during the semester. According to Deci and Ryan's Self-Determination Theory (2000), intrinsic motivation is strengthened when students' needs for competence, autonomy, and relatedness are met, which seems to have been promoted by the adopted pedagogical strategies.
- Perception of Purpose and Value in Activities: Before the intervention, students did not clearly perceive the purpose and value of the activities carried out, which may reflect pedagogical practices that failed to demonstrate the applicability of the content in real or future contexts. After the intervention, there was a significant increase in this perception. Adjustments in planning, such as presenting scenarios with practical applications and contextualizing the topics, helped students understand the relevance of what they were learning. According to Eccles and Wigfield (2002), when students perceive content as relevant to their lives, their engagement and willingness to learn increase.
- Interest in Learning More and Confidence in Activities: Before the intervention, many students showed little interest in deepening their knowledge and displayed low confidence in performing activities, indicating that the classes were not fostering curiosity or a sense of self-efficacy. After the interventions, interest and confidence increased significantly. This can be explained by the introduction of more dynamic and interactive activities, such as gamified practices, which encourage students to explore and learn playfully. According to Hamari, Koivisto, and Sarsa (2014), gamification is an effective tool for increasing interest and motivation by introducing elements of challenge and reward. Positive feedback and well-structured activities that allowed students to feel competent were also key to boosting self-confidence.
- Class Structure and Encouragement from Teachers and Peers Before the intervention: the organization of classes and the encouragement received from teachers and peers were perceived as not very motivating. The absence of a collaborative environment contributed to students feeling less supported. After the intervention, this perception changed positively. Pedagogical practices began to include opportunities for group work, role definition, and the promotion of effective communication. According to Vygotsky's Sociocultural Theory (1978), learning is enhanced in social and collaborative environments where students construct knowledge together, fostering a sense of community, motivation, and engagement.
- Progress in Learning and Development of Important Skills Before the intervention: students did not perceive significant progress in their learning or the development of applicable skills, suggesting that the activities carried out were not providing a meaningful or tangible learning experience. After the intervention, students reported a greater perception of progress and the development of skills considered important. The activities were reformulated to emphasize the relevance of the content and include constant feedback, aligning with Dweck's (2006) Growth Mindset approach. When students perceive progress in learning, they feel more confident to face new challenges and engage more actively in activities.

9 CONCLUSIONS

This research investigated the impact of pedagogical interventions based on gamification, content contextualization, and collaboration on the engagement and motivation of high school students during educational activities, using the game *Overcooked* as a support tool. The main objective was to understand how interactive pedagogical strategies can influence students' interest in subjects and promote the development of socio-emotional and cognitive skills, essential both for the school context and for students' personal development.

The study was structured with experimental groups and a control group, subjecting participants to different gameplay conditions, ranging from situations with and without instructions, with communication restrictions, and with specific

cooperation guidelines. The application of Likert scale-based questionnaires before and after the interventions enabled the measurement of changes in students' engagement and perceptions. The results showed a significant increase in motivation, sense of purpose, and the development of applicable skills after the introduction of methodological practices that encouraged interaction and contextualization of learning.

Despite the positive results, some limitations were identified. The experiment was conducted in a controlled environment and focused on a single specific game, which may hinder the generalization of findings to other subjects, games, or educational settings. Moreover, the results depend directly on students' receptiveness to the chosen game and teachers' ability to mediate and promote effective collaborative interactions. These variables may limit the applicability of the results in scenarios with different student, teacher, or infrastructure profiles.

Based on the results and observed limitations, this research proposes some directions for future work. It is recommended to expand the use of educational games to other content and subjects, exploring various forms of gamification that adapt to different pedagogical contexts and student profiles. Additionally, it would be valuable to investigate the sustainability of these practices in the long term, considering costs, planning time, and teacher training. Evaluating the feasibility of these strategies in educational environments with limited resources or greater cultural and socioeconomic diversity may provide relevant insights for consolidating and expanding the use of gamification as a pedagogical tool.

Finally, this research reinforces the importance of innovative and interactive methodologies in teaching, highlighting how the strategic use of gamification, contextualization, and collaboration can transform the learning experience, making it more engaging and meaningful for students.

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