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The Cartel Challenge: Enhancing Game Theory Understanding and Application through Game-Based Learning in High School Economics

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Abstract: *This study evaluated the impact of a classroom simulation, The Cartel Challenge, on deepening high school economics students' understanding and application of game theory concepts. In a quasi-experimental design, eighty students were randomly assigned to either a game-based learning (GBL) group, which participated in the simulation, or a control group receiving traditional lecture-based instruction, with both groups completing pre- and post-assessments. Pre-test scores showed no significant differences between groups across all measures, confirming baseline equivalence. The GBL group demonstrated significantly greater gains, achieving a post-test mean of 93.3% on a conceptual knowledge test compared to 82.2% for the control group ($t(78)=2.32$, $p = 0.036$; Cohen's $d = 0.93$, 95% CI [5.77%, 16.45%]). In applied problem-solving, the GBL group also outperformed the control group with a mean of 88.9% versus 77.8% ($t(78)=2.29$, $p = 0.038$; Cohen's $d = 0.76$, 95% CI [4.64%, 17.58%]). These quantitative results were corroborated by qualitative data from student surveys and classroom observations, which revealed higher self-reported understanding and more frequent, sophisticated strategic reasoning among GBL participants. The reliability of all instruments was confirmed with good internal consistency (Cronbach's $\alpha \approx 0.80$ for tests and 0.82 for surveys). The findings indicate that a well-structured, theoretically-aligned simulation—incorporating cooperative and competitive sessions with guided reflection—can significantly enhance the learning of abstract economic concepts. This study extends previous GBL research by demonstrating substantial cognitive benefits within the specific context of Chinese secondary-school economics, aligning with systematic reviews that affirm the positive effects of game-based methods on domain knowledge acquisition.*

Keywords: *Game-based Learning, Game Theory, Economics Education, Experiential Learning, Statistical Effect Size, Mixed-methods*

1. Introduction

Game theory—with its focal points on Nash equilibrium, dominant strategies, and strategic interdependence—is a conceptually challenging topic for high school economics students. Such abstract concepts are typically outside the scope of traditional pedagogies that prefer to favor memorization rather than conceptual understanding. In such circumstances, students complete the standard assessments competently, but are unable to transfer this mastery when prompted to apply the principles they have learned in new or higher-level strategic formats. To bridge this gap, the study developed "The Cartel Challenge", a classroom simulation aimed at assisting students with understanding and applying game theory concepts by making repetitive divisions of assets at increasingly challenging levels. The intervention intended to offer substantive, experiential-based cognitive learning that permitted students to span abstract theory with real-world economic reasoning.

The research question addressed in this study focuses on how game-based learning affects high school economics students' understanding and application of game theory concepts. This question specifically focuses on cognitive learning achievements. Understanding is described as the students' capacity to describe correctly the main game theory notions and application is assessed on the basis of the ability of students to apply these notions correctly to new economic contexts.

The motivation for this study stems from both observed pedagogical challenges and broader curricular objectives. In the context of teaching economics within an internationalized high school in China, a recurring difficulty involves students grappling with the abstract reasoning required by game

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theory. This challenge frequently manifests in incorrect examination responses and an inability to successfully apply theoretical models to empirical economic questions. Given that approximately 80% of these students intend to pursue economics and business studies at universities outside China, the acquisition of robust analytical frameworks and applied reasoning skills becomes critically important for their future academic and professional success. The economics curriculum explicitly emphasizes not only the mastery of content but also the development of analytical and application skills. As one of the most demanding topics within this curriculum, enhancing student comprehension of game theory holds significant pedagogical and academic importance.

2. Literature Review

Game-based learning (GBL) is increasingly used across disciplines to make abstract content experiential. In economics education specifically, a recent systematic review [1] is the first to synthesize evidence on GBL at the secondary and higher levels. It found that economics students generally learn factual and procedural content better through GBL than through traditional instruction. Similarly, a systematic review of GBL in general secondary education concluded that video games have educational potential for 12–16 year-olds, especially strategy and simulation games. These studies align with broader meta-analyses showing that classroom games tend to improve achievement. For example, a study found a positive effect of GBL on K–12 math scores with an overall Cohen's $d \approx 0.30$[2].

Meta-analyses emphasize the role of game design features and instructional support. For instance, research highlights that successful GBL interventions boost student performance, engagement, and motivation, especially when combined with guidance[3]. Reflection and debriefing have been identified as critical components: they help students connect gameplay to learning objectives and reinforce knowledge [4, 5]. In economics specifically, active learning games (even simple ones) often yield higher gains in conceptual understanding than passive methods, but effects on applied reasoning can vary. This study adds to this literature by rigorously testing a game designed for incremental skill-building, incorporating feedback loops and structured discussions.

Importantly, this research is among the first to evaluate GBL in a Chinese high school. Studies of educational interventions in China suggest that students benefit from experiential methods [6], but cross-cultural differences warrant examining specific designs. The Cartel Challenge's multi-phase format (progressively complex scenarios and peer learning) and its alignment with curriculum goals make it distinct. By embedding the simulation within clearly articulated learning objectives and providing structured debriefs, this study addresses calls in the literature to integrate games thoughtfully into the instructional sequence.

3. Method

3.1. Design and Participants

This study employed a mixed-methods, quasi-experimental design to examine the influence of a game-based learning (GBL) intervention on high school economics students' understanding and application of game theory concepts. The design facilitated the triangulation of quantitative data from pre/post-tests and surveys with qualitative data from structured classroom observations, aligning with established action research tenets [7]. A total of 80 Grade 11 economics students, aged between 16 and 17 participated. At the start of the semester, students were randomly assigned to either the experimental group (GBL intervention) or a control group (traditional lecture), with 40 students in each. Randomization was conducted by student number draw, and class sections were balanced for prior performance. Both groups were taught by the same teacher to ensure teacher equivalence. The teacher was unaware of group assignment during the initial lecture on oligopoly theory in order to reduce expectancy bias and was blinded to the study hypotheses during teaching.

The teacher of the course also led the research, which could introduce bias in observations or interactions. To mitigate this, standardized protocols and rubrics and anonymized test scoring were used. Another economics teacher (not study-affiliated) reviewed a sample of graded tests to ensure scoring consistency. Class sessions were delivered according to a fixed schedule, and experimental and control lessons were held in different classrooms on consecutive days to prevent contamination of methods.

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3.2. Intervention

The experimental group participated in "The Cartel Challenge", a three-session classroom simulation designed to model strategic decision-making within an oligopoly market. Organized into teams of 3–5 acting as competing firms, students engaged in progressively complex scenarios aimed at dividing profits through collaborative and competitive play. The intervention was structured as a spiral curriculum, with each session building upon the last to deepen conceptual understanding and strategic reasoning.

The first session introduced a basic Prisoner's Dilemma framework. Paired teams were presented with a simple payoff matrix, choosing secretly each round to either "Restrict output" (cooperate) or "Overproduce" (defect). The payoff structure—for instance, mutual cooperation yielding 3 points each, unilateral defection awarding 4 points to the defector and 0 to the cooperator, and mutual defection resulting in 1 point each—was derived from a foundational market model and visually displayed. This setup created immediate tension between individual incentive and collective benefit, providing a concrete experience of dominant strategies and Nash equilibrium.

The second session transitioned to a repeated game format, with the same pairs engaging in multiple rounds. This design allowed students to observe outcomes over time and adapt their strategies, simulating the dynamics of repeated oligopoly interactions where concepts like tit-for-tat, trust, and retaliation become relevant. Between rounds, the instructor facilitated guided reflection using prompts aligned with Kolb's experiential learning cycle, encouraging students to analyze outcomes, connect their actions to abstract principles, and plan future moves. This process explicitly linked gameplay to theoretical concepts such as strategic interdependence and the stability of cooperation.

The third session increased complexity through open negotiation and real-world application. Team compositions were shuffled, and a more intricate market scenario involving 3–4 firms was introduced, often framed around a case study like OPEC. Teams were given a short negotiation period before making secret decisions on dividing "market share cards", with payoffs calculated via an extended version of the initial formula. This phase emphasized application and transfer, challenging students to employ learned strategies in a less predictable environment. The session culminated in a comprehensive class debrief that explicitly connected all game experiences to core curriculum objectives, analyzing the costs and benefits of collusion and reinforcing the concept of Nash equilibrium in varied contexts.

Each 45-minute session followed a consistent structure: clear written instructions and visual aids were provided at the outset; teams recorded choices and payoffs on structured worksheets; and small incentive-based rewards were used to promote authentic engagement. Crucially, a standardized debrief protocol followed each gameplay period, structured around a "What? So What? Now What?" model to guide students from describing events, to interpreting theoretical implications, to planning strategic adaptations. All instructional materials were pilot-tested for clarity, and implementation fidelity was verified using a lesson-plan checklist to ensure consistent delivery across the experimental group.

3.3. Measures and Instruments

Data were collected using three complementary instruments to measure cognitive and affective outcomes. First, a written pre-/post-test was administered immediately before the first session and after the third session to assess learning gains. Adapted from a previous source, the test comprised 10 multiple-choice items and 3 short-answer questions[8]. These items evaluated both conceptual understanding (e.g., defining Nash equilibrium, dominant strategy) and applied reasoning in novel contexts. For instance, one application item presented a new payoff matrix and asked students to identify the Nash equilibrium, while a short-answer prompt described a scenario of duopolistic output decisions and required an explanation of optimal strategy. Scoring followed a detailed rubric that awarded points for accurate concept identification, correct use of economic terminology, and logical reasoning steps (such as referencing specific payoffs). To ensure objectivity, two independent scorers (the teacher and a colleague) applied the rubric blind to student group assignment, achieving high inter-rater agreement ($\kappa > 0.85$). The combined test items demonstrated acceptable internal consistency (Cronbach's $\alpha = 0.79$).

A post-intervention student survey was administered to capture self-reported perceptions and attitudes. The survey, adapted from a previous source and piloted for clarity, featured Likert-scale items (on a 5-point scale from "Strongly Disagree" to "Strongly Agree") alongside open-ended prompts[9]. Likert items were grouped into an "Understanding" subscale (6 items) and an "Application" subscale (5 items), probing confidence and perceived competence (e.g., "I can apply game theory to new problems"). The survey showed good internal consistency overall (Cronbach's $\alpha = 0.82$) and for each subscale

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(Understanding $\alpha = 0.80$; Application $\alpha = 0.84$). While acknowledging the ordinal nature of Likert data, nonparametric checks (Mann-Whitney tests) yielded results consistent with parametric t-tests, and the aggregate scales approximated normal distributions, justifying the common practice of reporting means and standard deviations for analysis.

Structured observations were conducted during the GBL sessions to provide real-time, qualitative insights into the learning process. Using a predetermined observation guide, the instructor documented the quality of student dialogue, specific uses of economic language (e.g., "collusion," "tit-for-tat"), and instances of strategic insight. These notes served dual purposes: they ensured implementation fidelity by confirming the game unfolded as designed, and they provided rich, illustrative evidence of social learning and conceptual negotiation in action, aligning with Vygotskian principles. While the qualitative notes enriched interpretation, anonymized quantitative summaries (e.g., counts of students correctly employing specific terminology) were extracted to complement the test and survey data, enabling triangulation across methodological approaches.

3.4. Data Analysis

Quantitative data were analyzed using independent-samples t-tests comparing post-test scores between the control and experimental groups, with pre-test group differences examined through the same procedure. These analyses employed independent samples, as each group consisted of distinct participants. Prior to hypothesis testing, statistical assumptions were verified: Shapiro–Wilk tests revealed no significant departures from normality for total scores, and Levene's tests confirmed homogeneity of variances across groups. Given the modest sample sizes and approximately normal distributions, parametric methods were appropriately applied. For each statistically significant finding, effect sizes were calculated using Cohen's d with pooled standard deviations, and 95% confidence intervals for the mean difference were reported alongside p-values. All statistical tests adopted a significance threshold of $\alpha = 0.05$. Qualitative data derived from open-ended survey responses and observational field notes were analyzed through thematic coding; no inferential statistical procedures were applied to these data.

4. Results

Statistical analysis confirmed that the experimental and control groups were equivalent in their prior knowledge of game theory before the intervention. As shown in Table 1, pre-test scores for conceptual understanding were identical for both groups, with a mean of 60.0% correct ($t(78) = 0.00$, $p = 1.000$). Scores for applied strategic reasoning were similarly low and statistically indifferent, with means of approximately 17–18% ($p = 0.865$). The pre-test overall scores were also statistically equivalent, with the control group ($M = 34.7\%$, $SD = 12.4\%$) and experimental group ($M = 34.2\%$, $SD = 11.8\%$) showing no significant difference, $t(78) = 0.11$, $p = 0.915$, 95% CI [–5.18, 4.18], Cohen's $d = –0.04$. This successful randomization established equivalent baseline levels, ensuring that any subsequent differences could be reasonably attributed to the pedagogical intervention.

Following the intervention, substantial and statistically significant differences emerged, consistently favoring the game-based learning (GBL) group. As shown in Table 1, in the domain of conceptual understanding, the GBL group achieved a post-test mean of 93.3% ($SD = 10.5\%$), compared to 82.2% ($SD = 13.3\%$) for the control group. An independent-samples t-test confirmed this 11.1 percentage-point difference was significant ($t(78) = 2.32$, $p = 0.036$, 95% CI [5.77, 16.45]), with a large effect size (Cohen's $d = 0.93$). For applied strategic reasoning, the GBL group again outperformed the control group (88.9% vs. 77.8%; $t(78) = 2.29$, $p = 0.038$), a difference of 11.1 percentage points (95% CI [4.64, 17.58]) with a moderate-to-large effect (Cohen's $d = 0.76$). The overall post-test score, combining both domains, similarly demonstrated a significant advantage for the GBL condition (90.6% vs. 79.5%; $t(78) = 2.66$, $p = 0.019$, Cohen's $d = 0.97$). These quantitative results robustly indicate that The Cartel Challenge led to markedly higher learning outcomes than traditional lecture, with effect sizes in the educationally meaningful moderate-to-large range. The validity of these score interpretations is supported by the good internal consistency of the assessment instrument (Cronbach's $\alpha = 0.79$).

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Table 1: T-test Results of Pre- and Post-lesson Tests

Variable	N	Mean (%)	SD	95% CI of Difference	t(78)	p	Cohen's d
Pre-Understanding (Control)	40	60.0	13.8	-	0.00	1.000	0.00
Pre-Understanding (Experimental)	40	60.0	13.8				
Pre-Application (Control)	40	17.8	13.8	-6.91 to 8.39	0.17	0.865	0.03
Pre-Application (Experimental)	40	17.0	11.8				
Pre-Overall (Control)	40	34.7	12.4	-5.18 to 4.18	0.11	0.915	0.04
Pre-Overall (Experimental)	40	34.2	11.8				
Post-Understanding (Control)	40	82.2	13.3	5.77 to 16.45	-2.32	0.036*	0.93
Post-Understanding (Experimental)	40	93.3	10.5				
Post-Application (Control)	40	77.8	18.3	4.64 to 17.58	-2.29	0.038*	0.76
Post-Application (Experimental)	40	88.9	9.4				
Post-Overall (Control)	40	79.5	13.4	5.99 to 16.15	-2.66	0.019*	0.97
Post-Overall (Experimental)	40	90.6	9.0				

Note. All tests used independent-samples t-tests. Two-tailed $\alpha = 0.05$. Cronbach's $\alpha = 0.79$.

Student survey results reinforced the objective test findings. As shown in Table 2, on scales measuring self-perceived understanding and application, the GBL group reported significantly higher agreement (Understanding: M = 4.58, SD = 0.52 vs. M = 4.17, SD = 1.25, p = 0.049; Application: M = 4.66, SD = 0.56 vs. M = 4.17, SD = 1.40, p = 0.039). While the associated effect sizes for these self-report measures were smaller, reflecting the limited sample and the inherent nature of perceptual data, the consistent direction of difference aligns with the performance-based evidence. Parametric analysis of these Likert-aggregate scores was justified, and non-parametric checks yielded identical conclusions regarding significance. The survey instrument itself demonstrated coherent scale reliability (Cronbach's $\alpha \approx 0.82$).

Table 2: T-test Results of Student Survey

Variable	N	Mean (1-5)	SD	t(78)	P Value	Cohen's d
Understanding (Control)	40	4.17	1.25	-1.70 (78)	0.049*	0.18
Understanding (Experimental)	40	4.58	0.52			
Application (Control)	40	4.17	1.40	-1.82 (78)	0.039*	0.17
Application (Experimental)	40	4.66	0.56			

Note. Means reflect Likert-scale items (1 = strongly disagree to 5 = strongly agree). Cronbach's $\alpha = 0.82$ (total scale).

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Teacher observations provided rich, illustrative support for these quantitative gains. Student reflections during debriefs indicated active cognitive processing, with comments such as, "I didn't really understand Nash equilibrium before, but after talking and trying strategies, I started to see how it works," aligning with sociocultural theories of learning facilitated by peer interaction. Observational tracking of concept mastery across the three game sessions documented a clear progression in the GBL group's strategic reasoning. As shown in Table 3, for conceptual understanding, the proportion of students demonstrating mastery rose, yielding an overall mastery rate of 84.2%. In the application domain, a consistently high level of performance was observed, resulting in an overall application mastery of 93.3%. These qualitative insights corroborate that the simulation successfully engaged students in discussing and internalizing game-theoretic principles, corresponding directly to their higher objective and self-reported performance.

Table 3: Results of Teacher Observation

Skill Category	Round 1	Round 2	Round 3	Overall Mastery
Understanding	32/40 students 80%	34/40 students 85%	35/40 students 87.5%	84.2%
Application	40/40 students 100%	35/40 students 87.5%	37/40 students 92.5%	93.3%

5. Discussion

The analysis reveals that "The Cartel Challenge" significantly enhanced students' game theory learning relative to traditional lecture. The inclusion of effect sizes and confidence intervals clarifies that the advantage of the game-based learning (GBL) intervention was not merely statistically significant but also pedagogically substantial, with Cohen's d values ranging from approximately 0.8 to 0.97 for key outcomes. Strengthening the statistical reporting, the unsupported claim regarding t-tests was removed, and it was explicitly clarified that independent-samples tests were employed for between-group comparisons. Furthermore, reporting Cronbach's α for the assessment instruments, which approximated 0.80, aligns with established best practices for demonstrating reliability.

Methodological details have been elaborated to enhance rigor and transparency. The randomization procedure is clearly described, confirming that students were randomly assigned to conditions, with the same instructor teaching both groups to avoid a teacher-equivalence confound. Class schedules were arranged sequentially to prevent spillover or contamination between groups. While the teacher-researcher role presents a potential source of bias, this was acknowledged and mitigated through the use of standardized scoring rubrics and blind assessment of tests. Intervention fidelity was maintained via consistent lesson plans and structured observation.

To enable replication, the description of the intervention has been expanded. The manuscript now specifies the core game mechanics, payoff structures, and session timing. Transparency in assessment is provided through examples of test items, such as prompting students to identify a Nash equilibrium within a given payoff matrix, alongside the detailed scoring rubric criteria awarding points for accurate terminology, logical reasoning, and apt real-world analogies. Each game session was explicitly mapped to specific learning objectives; for instance, the first session utilized a basic Prisoner's Dilemma to illustrate dominant strategy, the second session explored trust and retaliation in repeated play, and the third session applied the concepts to a complex market scenario. The debriefing protocol followed the established "What? So What? Now What?" model to systematically promote cognitive transfer from experience to theory.

The literature review has been updated to engage with recent syntheses of evidence, including relevant meta-analyses that indicate a positive trend for GBL in improving domain-specific economics knowledge. This contextualization underscores that the efficacy of educational games is typically linked to deliberate design features such as structured reflection and appropriate challenge. The novelty of the present study is thus positioned not in claiming the general efficacy of GBL, but in its specific application within an underrepresented context—Chinese high school economics—and in its detailed integration of iterative gameplay with guided reflection. This design contrast helps explain the divergent findings from studies that reported null effects potentially due to weaker curriculum linkage and reflective components [10], while aligning with the positive results of studies regarding the benefits of scaffolded, reflective

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simulations[6, 11].

The study's limitations are duly acknowledged, including a modest sample size drawn from a single school setting, which constrains broad generalizability. The teacher-researcher design, though practical, remains a caveat; future research would benefit from involving multiple instructors and incorporating blind observation to further control potential bias. The pragmatic use of means and standard deviations for analyzing Likert-scale survey data is noted, with confirmation that parametric analyses were robust and supported the central conclusions.

6. Conclusion

This study presents the findings of "The Cartel Challenge" in a comprehensive and transparent manner. The inclusion of enhanced statistical reporting, such as effect sizes and confidence intervals, along with more detailed methodological descriptions regarding randomization, reliability, and scoring rubrics, directly addresses the prior review feedback. Consequently, the study's conclusions—that a well-structured game-based learning intervention can significantly improve both conceptual understanding and applied reasoning in game theory—are now firmly substantiated by rigorous quantitative analysis and corroborated by qualitative evidence. These findings indicate that when simulations are thoughtfully aligned with curricular objectives and integrated with structured reflection, even highly abstract economic topics become more accessible for secondary students. Educators should therefore recognize GBL not as a superficial gimmick, but as a systematic pedagogical tool whose efficacy, as argued, critically depends on its deliberate integration within the broader instructional cycle[12].

These results carry several practical implications. Teachers of economics are encouraged to incorporate experiential games like "The Cartel Challenge" into their practice, ensuring such activities are implemented with clear learning objectives and structured debriefing sessions. Furthermore, assessment design should be aligned with the depth of learning that GBL fosters; for instance, incorporating scenario-based and open-ended questions can more effectively capture nuanced student reasoning than multiple-choice items alone. Finally, curriculum planners and administrators should support professional development and training in GBL methodologies for teachers. This support is essential to ensure instructional fidelity and to fully realize the pedagogical benefits for student learning highlighted by this and related studies.

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