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GAME-BASED LEARNING OF MICROECONOMICS BY UNDERGRADUATE ENGINEERING STUDENTS: EVIDENCE FROM HONG KONG

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ABSTRACT

Noticing the problems with *traditional ways of teaching* microeconomics and motivated by the growing interest in game-based learning, this paper presents the first study of integrating a commercially available computer game as an additional complementary learning tool into a compulsory introductory microeconomics course taken by 450 Chinese-speaking engineering undergraduate students at a Hong Kong university. We use a game-based learning design for the course and conduct a survey to collect the data for determining student perceptions of and experiences with the computer game. We develop a statistical model to delineate the effects of different drivers of a student's scores in the computer game and mid-term and final exams to assess the students' learning outcomes, finding that the computer game is only marginally effective in enhancing the students' learning of microeconomics. The results of our study lead to practical recommendations for an integrated approach for successful game-based learning, which are useful for academics interested in using a computer game to teach microeconomics or other business subjects.

Keywords: Economics Education; Undergraduate Economics; Game-based Learning; Microeconomics; Hong Kong.

INTRODUCTION

In UK and the US, the teaching of microeconomics at university level has long been following a content-driven, lecture-tutorial approach that uses textbooks and tutorial question sets as the major learning materials (Becker and Watts, 1998; Forsythe, 2002; Siegfried, 1998). The situation is no different for Hong Kong. At the university where the first author is currently teaching, students studying introductory microeconomics are required to attend a 2-hour lecture and 1-hour tutorial per week for 13 teaching weeks. During the lectures, lecturers focus on explaining the subject content of topics, whereas in the tutorials, we require students to prepare answers to conceptual questions and form groups to present them to the class. To assess learning progress and overall learning outcome, we use a mid-term test held in the middle of the semester and a final examination after the last lecture week. Our experience with this traditional way of teaching indicates a major problem: students can readily

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memorize and repeat economics concepts, but they cannot evaluate the knowledge they have learnt and use it compellingly at the right time and context. Among the non-traditional methods as suggested in the literature (e.g., classroom experiments, case studies, games and simulations), we have tried to use case studies and newspaper articles, which are still inadequate for developing students' problem-solving skills and increasing their ability to apply concepts in the right context. Hence, our experience with these non-traditional methods is not at odds with the limited evidence in the literature (Reimann, 2004). Supported by two university teaching development schemes, the first author visited a renowned university in Australia to observe the learning and teaching practices for microeconomics. Following the visit and discussions with education experts, we incorporated game-based learning, a complementary learning method that we have explored overseas, into the teaching of introductory microeconomics within the local context. This paper reports our integration of game-based learning as an additional complementary learning tool into an introductory microeconomics course taken by undergraduate engineering students at a Hong Kong university. It uses an empirical approach to (a) assess the effectiveness of game-based learning of microeconomics in improving student learning outcomes, and (b) provide useful recommendations on the integrating approach for academics interested in using computer games to teach microeconomics.

Game-Based Learning

Games have long been used in education, with the earliest games used to support training and learning (Coleman, 1971). Rapid advances in technology and declines in cost, widespread internet access, and the growing popularity of computer games have led to a surge in 'digital game-based learning' over the past 20 years (Perrotta *et al*., 2013; Prensky, 2001). Games provide a contextual environment that foster different skill acquisitions, including problem solving skills, communication and collaboration skills and strategic thinking skills. Students develop their ability to retain information and apply what they have learnt in real-world situations when they engage in learning-based games. Well-designed games also incorporate good learning principles (Aguilera & Mendiz, 2003; Bransford *et al*., 2000; Gee, 2003, 2004, 2005; Prensky, 2001).

Earlier studies of game-based learning have mainly focussed on educator assessments (e.g., Connolly *et al*., 2012; Panoutsopoulos & Sampson, 2012; Saulter, 2007). The success of game-based learning, however, should mirror student learning outcomes, in addition to whether a game's design meets such criteria as instructional clarity and content coverage (O'Neil *et al*., 2014; Perrotta *et al*., 2013). This is because game-based learning is a multi-faceted process that goes far beyond the selection of a well-designed game. For example, inadequate support and motivation may cause students to see playing the selected game as a form of entertainment or a time-consuming activity with few learning benefits (Erhel & Jamet, 2013; Wouters & Oostendorp, 2013). Hence, game-based learning's success is unlikely *sans* an integrated approach to classroom implementation (Deubel, 2006; Van Eck, 2006). Highlighting the importance of an integrated approach, this paper reports the first experience of using game-based learning in a compulsory, English-language introductory microeconomics course taken by 450 undergraduate engineering students at a Hong Kong university. Over 95% of these students are native Chinese speakers. Relative to the university's business undergraduates, these students are generally more proficient in mathematics, less so in English. This presages a potential language barrier that may hinder their learning.

Table 1 summarises the student data collected from a survey conducted on the last lecture day of the first semester of the 2015-16 academic year. The students are mostly young Hong Kong men enrolled in the university's full-time electrical, transportation system, electronic and information, and industrial and systems engineering programmes.

Table 1: Demographic characteristics of the study sample of 280 students

Variable	Category	Number	Percentage
Age	18-29 years	258	92
	30-39 years	5	2
	Unreported	17	6
Gender	Female	70	25
	Male	210	75
High school economics?	Yes	56	21
	No	213	79
Region of origin	Mainland	53	19
	Hong Kong	213	76
	Other	14	5
Mode of study	Full time	193	73
	Part time	72	27

The chosen computer game is the off-the-shelf, commercially available 'Beat the Market Online: An Interactive Microeconomics Game' (BMOL Game hereafter),[1] accessible online

[1]The first author and another lecturer teaching introductory economics reviewed 'Playconomics'(http://www.lionsheartstudios.com), 'Five Market Games for Teaching Economics' (http://www.economics-games.com), 'The Competitive Strategy Game'(https://csg.haas.berkeley.edu) and the BMOL Game. They selected the BMOL Game based on its on-screen instructions, easy integration into the curriculum, good match with subject content, automatic grading strategy, low cost, and excellent technical support. Further information about the BMOL Game is available at:

24/7 to all students in the course. The BMOL Game contains simulation games and exercises designed to facilitate learning key microeconomics concepts and applications. With an 'online consultant' available to guide students, the BMOL Game's integration follows the advice of its designer, based on discussions with the university instructors about their curriculum content, lesson plan, assessment method, and learning objectives. This paper aims to answer three interrelated research questions.

First, do students find the BMOL Game's exercises and games useful in learning introductory microeconomics? This question directly addresses the usefulness of game-based learning, as a complementary learning tool for learning microeconomics as per the literature reviewed by Backlund & Hendrix (2013), Boyle *et al*. (2016), Clark *et al*. (2016), and Connolly *et al*. (2012). Second, what affects students' exercise and game scores? This question is related to issues of gender bias and the effects of student involvement and effort (Chou and Tsai, 2007; Connolly *et al*., 2012; Lucas & Sherry, 2004; Papastergiou, 2009; Paraskeva *et al*., 2010; Terlecki & Newcombe, 2005). Third, do students' mid-term and final exam scores move with their exercise and game scores? This question's answer measures the effectiveness of game-based learning in improving students' exam performance, taken herein as a proxy for learning success.[2]

To the best of our knowledge, our paper is the first study of game-based learning of introductory microeconomics in English by Chinese engineering students, many of whom aspire to a successful career in today's fast-changing global business environment. It complements early studies on non-traditional teaching methods of economics and provides solid evidences of students' learning outcomes now absent in the literature (e.g., Danny 2014; Reimann, 2004). Our paper's real-world relevance is that a solid understanding of microeconomics is an essential requisite for formulating business strategies and decisions. Good examples abound, including local and foreign infrastructure investments (e.g., electricity generation and transportation), commercialisation of product innovations (e.g., smart phones and electric cars), domestic and international e-commerce development (e.g., internet-based marketing and financing and the informational management of voluminous

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http://www.goldsimulations.com/economics-simulation-game/principles-of-microeconomics-for-college-and-mba.

[2] Exam performance is admittedly an imperfect measurement for two reasons. First, a low exam score may reflect the student's inability to fully understand the exam questions and answer those questions in English. Second, a student with a low exam score may have more appreciation than one with a high exam score of the role of microeconomics in business strategies and decisions. Nevertheless, the exam scores are our best available data for measuring learning success.

transaction data), and multi-national supply-chain management (e.g., integrated solutions for efficient product delivery and customer relationship management).

Our key findings are as follows. First, students' opinions of the BMOL Game's usefulness are neutral on average. Second, students' exercise and game scores depend on demographics (e.g., gender and mode of study), as well as involvement with and time spent on the exercises and games. However, there is no statistically significant evidence of gender bias whereby male students tend to outperform female students. Third, high exercise scores likely lead to high game scores, high mid-term exam scores, and high final exam scores. However, a student's game and final exam scores are weakly correlated, contrary to the studies of Delacruz (2011), Huang and Chen (2009), Kebritchi *et al*. (2010), and Miller and Robertson (2011). Taken together, our mixed findings on the learning effectiveness of the BMOL Game suggest further exploration of game-based learning of microeconomics at the university.

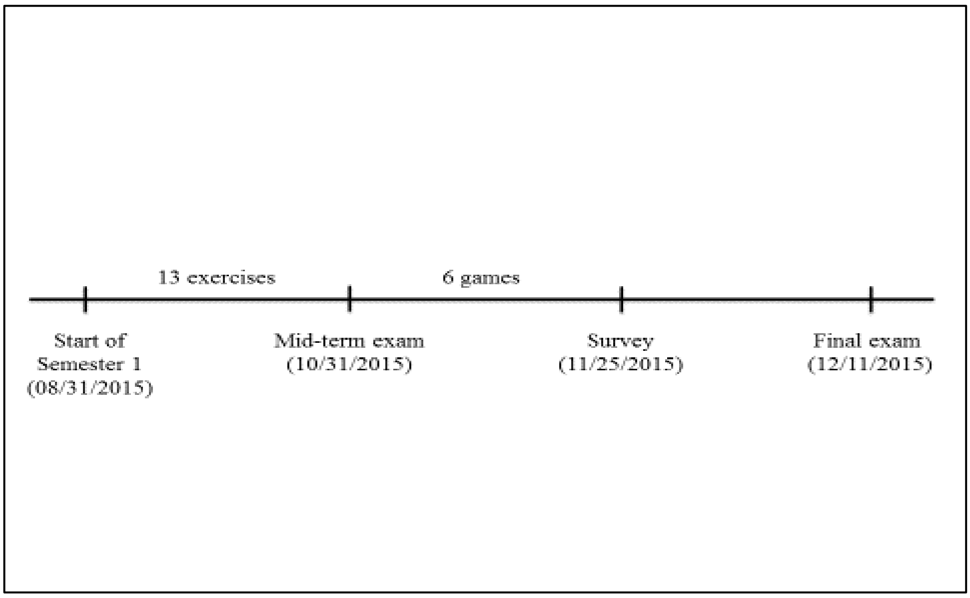
Our paper makes three contributions to the education literature on game-based learning of microeconomics. First, it proposes a regression-based approach to analyse the effectiveness of game-based learning of microeconomics. The proposed approach is general, applicable to other business games in accounting, finance, management, and marketing. Second, it comprehensively assesses the BMOL Game's learning effectiveness and discusses the implications for the game-based learning of microeconomics at the university. Finally, its findings lead to practical recommendations for an integrated approach to successful game-based learning, which are useful for academics interested in using computer games as complementary learning tools to teach microeconomics or other business subjects. The paper proceeds as follows. The data collection section describes the data used to estimate our proposed regressions. The results section reports the regression results. After discussing the implementation issues in the discussion section, the paper concludes with our recommendations for an integrated approach to successful game-based learning.

DATA COLLECTION

Exercise and Game Scores

Figure 1 portrays the design for collecting the students' exercise and game scores, covering the 13 teaching weeks between 8/31/2015 and 11/28/2015 of the 2015-16 academic year. The course syllabus required each student to complete 13 exercises (accounting for 5% of the final grade) before the mid-term exam (which made up 15% of the final grade). These exercises addressed such topics as market equilibrium, demand, elasticity, production, costs, revenue, and profit, thereby providing the necessary background for studying competition and market structure. If students failed to complete an exercise before the Sunday deadline, their exercise score for that week was zero.

Figure 1: Game-based learning design of the introductory microeconomics course taken by 450 undergraduate engineering students at the university



In each exercise, students first made specific decisions in an elementary game, then observed the results and answered questions. Students could repeat the exercise up to three times for experiential learning before submitting their final answers. A repeated exercise had the same questions but different starting data, thus preventing students from simply copying their earlier answers. After the mid-term exam, each student was required to play six advanced games about perfect competition and monopoly, making profit-seeking decisions for a hypothetical firm in response to changing market conditions. Students' game scores were based on their profit relative to that of the best-performing computer-managed firm.[3] Students had to complete all six games (which accounted for 5% of the final grade) before the final exam (which made up 50% of the final grade).[4] If students failed to complete a game by the deadline, the score for that game was zero.

Table 2 presents the descriptive statistics for the average scores on a 1-100 scale for the 13 exercises and six games, as well as the scores for the mid-term and final exams. The average exercise and game scores have similar means and small standard deviations. The mean score

[3] Suppose a student's profit is $20 and the computer-managed firm's profit is $50. The student's game score is then 40, reflecting a profit ratio of 40% (= $20/$50).

[4] One class presentation plus a report as well as class attendance and participation determined the remaining 25% of the final grade.

on the mid-term exam is about 74, higher than that of the final exam (about 59). The exam scores are much more disperse than the average exercise and game scores, plausibly due to students' differential exam preparation and performance under time constraints.

Table 2: Academic performance of 450 students

Score based on a 0-100 scale	Mean	Standard deviation	Minimum	Maximum
Exercises	69	0.29	0	100
Mid-term	74.4	13.6	35	100
Games	75	0.25	0	100
Final exam	58.6	18.4	6.5	96

Note: Exercises score = Average exercise score = Total exercise scores / 13 exercises; Games score = Average game score = Total game scores / 6 games.

Table 3 reports the score correlations. The mid-term and final exam scores are moderately correlated (r = 0.59), as are the average exercise and game scores (r = 0.66). The correlation between an average exercise/game score and an exam score is relatively low (r < 0.33), presaging the weak effects of game-based-learning on student exam performance.

Table 3: Score correlations

Variable	Average exercise score	Mid-term exam score	Average game score	Final exam score
Average exercise score	1	0.24	0.66	0.33
Mid-term exam score	0.24	1	0.17	0.59
Average game score	0.66	0.17	1	0.27
Final exam score	0.33	0.59	0.27	1

Student Survey

On the last lecture day of the semester, we asked the attendees to complete a written questionnaire, expressing their views of the computer-based exercises and games.[5] The response rate is 62.2%, reflecting 280 completed questionnaires from the population of 450 enrolled students.[6] We match each student's completed questionnaire and scores to obtain a

[5] The questionnaire is available by request from the first author.

[6] While the response rate is not 100%, the students attending the last lecture were likely more conscientious and keen on studying than those absent. The opinions of the absent students would likely exacerbate our mixed

database that allows a statistical assessment of the effects of game-based learning on academic performance. The questionnaire has three sections, taking approximately 20 minutes to complete. Section I surveys student attitudes towards the BMOL Game. These opinions are expressed on a scale of 1 = 'strongly disagree' to 5 = 'strongly agree', with 3 representing a 'neutral' opinion. Table 4 reports the average opinions and their standard deviations.

Table 4: Means and standard deviations (SD) of opinions (1 = 'strongly disagree' to 5 = 'strongly agree') expressed by the 280 survey respondents

I. Instructional content	Mean	S.D.
1. The instructions given by the lecturer for registration are easy to follow.	3.90	0.99
2. Information provided in the student manual is easy to understand.	3.56	1.05
3. It was clear to me how the exercises and games would be assessed.	3.36	1.12
4. It was clear to me what I was expected to learn from completing the exercises and games.	3.18	1.12
5. I have a clear understanding of the lecturer's introduction of the exercises and games.	3.53	0.98
6. The set of context game elements are related to learning objectives of the subject.	3.48	1.06
7. There are clear player goals of each topic in the exercises and games.	3.29	1.13
II. Game and exercise characteristics	Mean	S.D.
1. The game requirements are easy to understand.	2.99	1.15
2. The games provide an appropriate challenge to play.	3.12	1.20
3. The exercise questions provide an appropriate challenge to answer.	3.10	1.16
4. The competitive nature of the game increased the excitement of the game.	2.78	1.19
III. Learning outcome	Mean	S.D.
1. The games and exercises motivate me to learn the subject contents.	2.95	1.20
2. The games and exercises help stimulate my interest in the subject contents.	2.90	1.22
3. Playing the games allows me to have a better understanding of how equilibrium is achieved in different markets.	3.09	1.16
4. Playing the games allows me to have a better understanding of how price and production decisions change under various market conditions.	3.12	1.16
5. Playing the games allows me to have a better understanding of how elasticities are used to forecast demand and revenues.	3.18	1.15
6. Playing the games allows me to have a better understanding of how marginal analysis can be effectively utilised for decision-making.	3.07	1.17
7. Playing the games allows me to have a better understanding of how costs are related to plant size and optimal levels of production.	3.09	1.21
8. Completing the games and exercises gives me a sense of achievement/mastery.	2.99	1.20
9. I can see the relevance of the games and exercises to my studies.	3.14	1.15
10. The games and exercises help improve my understanding of the topics.	3.12	1.15

findings, as these students would likely have had below-average ratings of the BMOL Game due to missing some lectures on the subject content and game instructions.

11. Overall, as a learning experience, I would rate the computer games and exercises to be high.	2.93	1.12
IV. General preference for computer games and exercises	Mean	S.D.
1. In general, I enjoyed playing the games.	2.71	1.26
2. In general, I enjoyed doing the exercises.	2.67	1.23
3. In general, completing the games and exercises has provided me valuable learning experience and knowledge.	3.00	1.18

We use Table 4 to answer our first research question. The student opinions are on average neutral, with about half of the students finding the BMOL Game useful in enhancing their learning experience and knowledge. While somewhat unexpected, this finding is understandable in light of the game's implementation challenges, as noted below. Section II surveys student efforts on the exercises and games. Panel A of Table 5 reports the distributions of responses regarding the extent of involvement, average time spent on each exercise, average time spent on each game, and the challenge levels of exercises and games. Panel B presents the averages for these responses, showing that students were moderately involved, spent less than one hour on each exercise or game, and encountered medium levels of challenge. Finally, Panel C shows that involvement is uncorrelated ($|r| < 0.1$) with the amount of time spent or the challenge levels. The amount of time spent on exercises and games is positively correlated ($r = 0.65$), as are the challenge levels of exercises and games ($r = 0.59$). Section III uses open-ended questions to elicit students' views of the BMOL Game's most interesting/enjoyable aspect and worst aspect, as well as suggested changes. It also elicits any other comments that students may have.

Table 5: Involvement, time spent on and challenge levels of exercises and games

Panel A. Distribution of responses

Involvement			Average time spent on exercises			Average time spent on games			Challenge level of exercises			Challenge level of games		
Low	Medium	High	< 30 minutes	30-60 minutes	> 60 minutes	< 30 minutes	30-60 minutes	> 60 minutes	Low	Medium	High	Low	Medium	High
37	190	49	39	150	88	86	120	72	17	157	102	14	151	112

Panel B. Average responses based on (a) 1 for 'low', 2 for 'medium', and 3 for 'high'; and (b) 15 minutes for '< 30 minutes', 45 minutes for '30-60 minutes', and 75 minutes for '> 60 minutes'

Variable	Mean	Standard deviation
Involvement	2.04	0.56
Average time spent on exercises	50.31	19.64
Average time spent on games	43.49	22.61
Challenge level of exercises	2.31	0.58
Challenge level of games	2.35	0.58

Panel C. Correlations of responses based on (a) 1 for ‘low’, 2 for ‘medium’, and 3 for ‘high’; and (b) 15 minutes for ‘< 30 minutes’, 45 minutes for ’30-60 minutes’, and 75 minutes for ‘> 60 minutes’

Variable	Involvement	Average time spent on exercises	Average time spent on games	Challenge level of exercises	Challenge level of games
Involvement	1.00	0.04	0.07	-0.04	-0.09
Average time spent on exercises	0.04	1.00	0.65	0.24	0.26
Average time spent on games	0.07	0.65	1.00	0.13	0.17
Challenge level of exercises	-0.04	0.24	0.13	1.00	0.59
Challenge level of games	-0.09	0.26	0.17	0.59	1.00

Statistical Model

While the last sub-section offers an initial understanding of the data, its descriptive nature does not suffice to answer the two remaining questions. Hence, we propose a statistical model to delineate the effects of various drivers of student scores to assess the learning outcome.

Our proposed model comprises four linear regressions with intercepts ($\gamma_1, \ldots, \gamma_4$) and random errors ($\varepsilon_{1k}, \ldots, \varepsilon_{4k}$), reflecting the data collection’s chronology summarised in Figure 1, with the 13 exercises followed by the mid-term exam, the six games, and the final exam:

Average exercise score of student $k = Y_{1k} = \gamma_1 + \boldsymbol{X}_{1k}\, \boldsymbol{\alpha}_1 + \boldsymbol{Z}_k\, \boldsymbol{\beta}_1 + \varepsilon_{1k}$; (1.a)

Mid-term exam score of student $k = Y_{2k} = \gamma_2 + \psi\, Y_{1k} + \boldsymbol{Z}_k\, \boldsymbol{\beta}_2 + \varepsilon_{2k}$; (1.b)

Average game score of student $k = Y_{3k} = \gamma_3 + \lambda\, Y_{1k} + \boldsymbol{X}_{3k}\, \boldsymbol{\alpha}_3 + \boldsymbol{Z}_k\, \boldsymbol{\beta}_3 + \varepsilon_{3k}$; (1.c)

Final exam score of student $k = Y_{4k} = \gamma_4 + \theta_1\, Y_{1k} + \theta_2\, Y_{2k} + \theta_3\, Y_{3k} + \boldsymbol{Z}_k\, \boldsymbol{\beta}_4 + \varepsilon_{4k}$. (1.d)

Based on the intuition that a student’s average exercise score should depend on the student’s involvement and time spent, equation (1.a) uses $\boldsymbol{X}_{1k}$, a row vector of four binary indicators, to explain student k’s average exercise score Y_{1k}. For easy interpretation and without any loss of generality, these indicators reflect deviations from the reference case of medium involvement and 30-60 minutes spent.[7]

[7] Our initial data exploration included binary indicators for low and high challenge levels as regressors. Since the coefficient estimates for these variables were insignificant (p-value > 0.1) for all four equations, we excluded them from the final regression specification.

The first indicator is 1 for low involvement and 0 otherwise, and the second is 1 for high involvement and 0 otherwise. Similarly, the next two binary indicators show the amount of time spent on exercises: under 30 minutes and over 60 minutes. The effect of $\boldsymbol{X}_{1k}$ on Y_{1k} is given by the coefficient vector $\boldsymbol{\alpha}_1^{\mathrm{T}} = (\alpha_{11}, \ldots, \alpha_{14})$. We expect student exercise scores to increase with the degree of involvement (i.e., $\alpha_{11} < 0$ and $\alpha_{12} > 0$) and average time spent (i.e., $\alpha_{13} < 0$ and $\alpha_{14} > 0$).

We postulate students' average exercises score vary with demographics. Hence, the right-hand-side of equation (1.a) has $\boldsymbol{Z}_k$, a row vector containing: (a) students' class attendance/participation on a scale of 1 to 100; and (b) binary indicators for gender: male vs. female; region of origin: Hong Kong vs. Mainland; high school economics: yes vs. no; and mode of study: full time vs. part time.

We choose these demographic variables to answer the following auxiliary questions:
Question 1: Do class attendance and participation affect student scores? We expect the scores to increase with diligence.
Question 2: Is there a gender bias? The literature on game playing suggests that male students may outperform female students (Gee 2007; Unlusoy *et al*. 2010), a readily testable hypothesis in our regression analysis.
Question 3: Do students' regions of origin matter? The university is highly selective in admitting Mainland students into its undergraduate engineering programmes, implying that Mainland students on average outperform Hong Kong students.
Question 4: Does prior exposure to economics alter average student scores? We expect students with high school economics to outperform those without.
Question 5: Do full-time students have higher scores than part-time students? Full-time students have more time available to study, but working part-time students may be more motivated than full-time students. As a result, the net effect of the mode of study is an empirical issue explored in our regression analysis.

Equation (1.b) explains student k's mid-term exam score Y_{2k} using the student's exercise score Y_{1k} and demographic vector $\boldsymbol{Z}_k$.[8] The coefficient ψ is positive if a higher exercise score leads to a higher mid-term exam score. The effect of $\boldsymbol{X}_{1k}$ on Y_{2k} is measured by $\psi\boldsymbol{\alpha}_1$.

Equation (1.c) is similar to equation (1.a). We include a student's exercise score Y_{1k} as a regressor to test if students with high exercise scores also have high game scores (i.e., $\lambda > 0$).[9] In addition to the student's demographics $\boldsymbol{Z}_k$, it explains student k's game score using $\boldsymbol{X}_{3k}$ =

[8] As all exercises were completed before the mid-term exam, Y_{1k} is a pre-determined variable in equation (1.b).

[9] As reasoned in *supra* note 10, Y_{1k} is a pre-determined variable in equation (1.c).

row vector of binary indicators for the game-related data, defined analogously to $\boldsymbol{X}_{1k}$. The effect of $\boldsymbol{X}_{3k}$ on Y_{3k} is measured by the coefficient vector $\boldsymbol{\alpha}_3^{\mathrm{T}} = (\alpha_{31}, \ldots, \alpha_{34})$. We expect game scores to increase with the degree of student involvement (i.e., $\alpha_{31} < 0$ and $\alpha_{32} > 0$) and average time spent (i.e., $\alpha_{33} < 0$ and $\alpha_{34} > 0$).

Equation (1.d) explains student k's final exam score Y_{4k} using his/her exercise score Y_{1k}, mid-term exam score Y_{2k}, game score Y_{3k}, and demographics $\boldsymbol{Z}_k$.[10] When the coefficients (θ_1, θ_2, θ_3) are all positive, higher average scores on exercises, the mid-term exam, and games lead to a higher final exam score. The exercise-related effect of $\boldsymbol{X}_{1k}$ on Y_{4k} comprises two components: the direct component of $\theta_1\boldsymbol{\alpha}_1$ and the indirect component of $\theta_2\psi\boldsymbol{\alpha}_1$ through the mid-term exam score. The game-playing effect of $\boldsymbol{X}_{3k}$ on Y_{4k} is $\theta_3\boldsymbol{\alpha}_3$.

Equations (1.a) to (1.c) show that Y_{1k}, Y_{2k} and Y_{3k} move with student demographics, potentially rendering $\boldsymbol{Z}_k$ unnecessary in equation (1.d). In other words, equation (1.d) may be over-specified, yielding imprecise coefficient estimates that can be difficult to interpret. Hence, we re-estimate equations (1.a) to (1.d) under the restriction $\boldsymbol{\beta}_4 = \mathbf{0}$ to check the robustness of our regression results.

In summary, equations (1.a) to (1.d) represent a statistical model that relates students' exam scores to their exercise and game scores, which are presumably driven by involvement and time spent as well demographics. Thus, the model delineates the effects of exercises and games on student exam performance. If these effects are found to be statistically insignificant (p-value > 0.10), we infer that the BMOL Game is ineffective in improving an engineering student's exam-based learning outcome of introductory microeconomics at the university.

We use the seemingly unrelated regressions (SUR) method in PROC MODEL of SAS/ETS to estimate equations (1.a) to (1.d).[11] This estimation recognises that: (a) the random errors are contemporaneously correlated because each set of observed scores comes from a given student; and (b) the random errors are likely heteroscedastic because the estimation sample is a cross-section of 280 students (Wooldridge, 2010).

[10] Equation (1.d) treats Y_{1k}, Y_{2k} and Y_{3k} as pre-determined variables because the exercises, games, and mid-term exam occurred before the final exam.

[11] The detailed documentation of PROC MODEL is available at:
http://support.sas.com/documentation/cdl/en/etsug/60372/HTML/default/viewer.htm#model_toc.htm.

RESULTS

Table 6 reports the SUR results. The adjusted R^2 values are between 0.153 and 0.471, indicating that equations (1.a) to (1.d) have a reasonable fit for a cross-sectional sample of students with diverse attributes. The *p*-values of the White (1980) test statistic indicate heteroskedastic errors for equations (1.a) and (1.c), implying that heteroscedasticity-consistent standard errors should be used for gauging the statistical significance of the coefficient estimates. The rest of this section discusses each regression's estimated coefficients of primary interest.

Table 6: Seemingly unrelated regressions based on equations (1.a) to (1.d); values in ( ) = heteroskedasticity-consistent standard errors (White, 1980); sample size = 280 observations; * = '*p*-value < 0.01', ** = '*p*-value < 0.05', * = '*p*-value < 0.10'**

Estimate	Average exercise score	Mid-term exam score	Average game score	Final exam score
Adjusted R^2	0.153	0.250	0.315	0.471
p-value of the White test statistic for H_0: Homoscedastic errors	0.075	0.526	0.030	0.292
Intercept	72.884 (4.622)***	59.156 (3.282)***	44.911 (5.997)***	-6.241 (6.490)
Average exercise score as a pre-determined variable		0.072 (0.029)**	0.373 (0.063)***	0.084 (0.040)**
Mid-term exam score as a pre-determined variable				0.600(0.073)***
Average game score as a pre-determined variable				0.021 (0.059)
Binary indicator: low involvement	-6.729 (5.383)		-0.999 (2.979)	
Binary indicator: high involvement	3.594 (1.055)***		0.223 (0.794)	
Binary indicator: average time spent on each exercise: < 30 minutes	-6.797 (4.978)			
Binary indicator: average time spent on each exercise: > 60 minutes	9.112 (3.041)***			
Binary indicator: average time spent on each game: < 30 minutes			-2.264 (2.280)	
Binary indicator: average time spent on each game: > 60 minutes			-0.976 (2.366)	
Binary indicator: male	-7.034 (3.006)**	0.292 (1.650)	0.150 (1.809)	1.677 (1.728)
Binary indicator: full-time student	-2.245 (2.968)	6.017 (1.627)***	4.835 (2.081)**	3.384 (1.839)*
Binary indicator: high school economics	3.219 (3.931)	8.333 (1.864)***	-1.902 (2.325)	2.763 (2.100)
Binary indicator: Mainland student	16.514 (3.964)***	10.444 (1.865)***	1.732 (1.991)	4.951 (2.261)**
Class attendance and participation	0.732 (1.039)	1.030 (0.571)*	1.917 (0.732)***	3.038 (0.612)***

The Average Exercise Score Regression

The coefficient estimates of the average exercise score regression suggest that involvement matters because the score of a student with low (high) involvement is 6.7 (3.6) below (above) that of a student with medium involvement. Time spent also matters because the score of a student who spent under 30 minutes (over 60 minutes) is 6.8 below (9.11 above) that of a student who spent 30-60 minutes. A male student's exercise score is 7.0 *lower* than a female student's, thus rejecting the gender bias hypothesis. Statistically insignificant is the dependence of a student's exercise score on class attendance and participation and mode of study, as well as whether the student had high school economics. A Mainland student's average exercise score is 17 points significantly higher (p-value < 0.01) than a Hong Kong student's.

The Mid-term Exam Score Regression

The mid-term exam score regression suggests that a 1-point increase in a student's exercise score leads to an estimated 0.07 points increase in his/her mid-term exam score. As a result, a highly involved student who on average spent over 60 minutes on exercises is estimated to have a mid-term exam score about 0.9 points [= (3.60 + 9.11) from the average exercise score regression × 0.07] higher than a student with medium involvement and 30-60 minutes of time spent. For a student with low involvement and under 30 minutes of time spent, his/her score is about 0.9 points lower [= (6.73 + 6.80) from the average score exercise regression × 0.07]. Hence, exercise-related involvement and time spent only have a small positive effect on mid-term exam performance. The coefficient estimates for student demographics indicate an insignificant gender bias. However, a Mainland full-time student who had high school economics is estimated to have a mid-term exam score 25 points (= 6.02 + 8.33 + 10.44) higher than a Hong Kong part-time student without high school economics. High class attendance and active participation further magnify this difference.

The Average Game Score Regression

The average game score regression suggests that a 1-point increase in a student's exercise score leads to an estimated 0.37 points increase in his/her average game score. Thus, the game score of a highly involved student who on average spent over 60 minutes on exercises is estimated to be 4.7 points [= (3.59 + 9.11) from the average exercise score regression × 0.37] higher than a student with medium involvement and 30-60 minutes of time spent. For a student with low involvement and under 30 minutes of time spent, his/her score is about 5.0 points lower [= (6.73 + 6.80) from the average score exercise regression × 0.37]. Thus, exercise-related involvement and time spent have a discernible positive effect on a student's game score.

This regression suggests that game-related involvement and time spent have insignificant effects on a student's game score. This seemingly counterintuitive result is possibly due to the positive correlation between the exercise- and game-related involvement and time spent.

In other words, once the exercise-related factors are captured through the average exercise score, the effects of the game-related factors on the game score are diluted to insignificance. The remaining coefficient estimates suggest that the mode of study and class attendance and participation are statistically significant drivers of a student's average game score. However, the same does not apply to the binary indicators for gender, high school economics, and whether the student is from the Mainland.

The Final Exam Score Regression

The final exam score regression suggests that a 1-point increase in a student's exercise score leads to an estimated 0.084 points increase in his/her final exam score. A 1-point increase in a student's mid-term exam score is estimated to raise his/her final score by 0.6 points. Based on our discussion of the mid-term exam score regression results, we infer that exercise-related involvement and time spent have a small positive effect on the final exam score. The coefficient estimate for a student's average game score is 0.021, which is small and insignificant (p-value > 0.1). It suggests that game playing does not have a discernible effect on students' final exam performance. The regression's remaining coefficient estimates suggest that a full-time Mainland student with high class attendance and active participation tends to have a higher final exam score than a part-time Hong Kong student with low class attendance and participation. Whether a student had high school economics does not seem to matter. Finally, male and female students are found to have comparable final exam performance, suggesting the absence of a gender bias.

Final Checks

To ascertain the robustness of our regression results, we perform two final checks. The first check entails imposing the restriction $\boldsymbol{\beta}_4 = \mathbf{0}$ to exclude the demographic variables in explaining a student's final exam score, yielding Table 7 that reports the SUR results thus obtained. As Tables 6 and 7 are very similar for the other regressions, we focus on the final exam score regression, which has an adjusted R^2 of 0.395, indicating a reasonable fit.

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Table 7. Seemingly unrelated regressions based on equations (1.a) to (1.d) after excluding student demographics from equation (1.d); values in ( ) = heteroskedasticity-consistent standard errors (White, 1980); sample size = 280 observations; ** = '*p*-value < 0.01', * = '*p*-value < 0.05', * = '*p*-value < 0.10'**

Estimate	Average exercise score	Mid-term exam score	Average game score	Final exam score
Adjusted R^2	0.153	0.249	0.315	0.395
p-value of the White test statistic for H_0: Homoscedastic errors	0.072	0.511	0.030	0.227
Intercept	71.698 (4.617)***	58.222 (3.270)***	44.125 (5.999)***	-16.41 (5.864)***
Average exercise score as a pre-determined variable		0.070 (0.029)**	0.372 (0.063)***	0.074 (0.038)*
Mid-term exam score as a pre-determined variable				0.816 (0.066)***
Average game score as a pre-determined variable				0.130 (0.061)**
Binary indicator: low involvement	-6.569 (5.375)		-0.868 (2.981)	
Binary indicator: high involvement	3.620 (1.055)***		0.268 (0.798)	
Binary indicator: average time spent on each exercise: < 30 minutes	-6.601 (4.978)			
Binary indicator: average time spent on each exercise: > 60 minutes	9.180 (3.045)***			
Binary indicator: average time spent on each game: < 30 minutes			-2.014 (2.280)	
Binary indicator: average time spent on each game: > 60 minutes			-1.026 (2.367)	
Binary indicator: male	-6.848 (3.011)**	0.477 (1.650)	0.283 (1.810)	
Binary indicator: full-time student	-2.073 (2.970)	6.186 (1.624)***	4.945 (2.079)**	
Binary indicator: high school economics	3.314 (3.938)	8.445 (1.880)***	-1.829 (2.328)	
Binary indicator: Mainland student	16.679 (3.964)***	10.662 (1.873)***	1.846 (1.996)	
Class attendance and participation	0.998 (1.037)	1.290 (0.570)**	2.100 (0.731)***	

The coefficient estimate for a student's average exercise score is 0.074, implying that exercise-related involvement and time spent are estimated to have a small positive effect on final exam performance. A 1-point increase in a student's mid-term exam score raises his/her final exam score by 0.816, affirming the positive correlation between the two exam scores reported in Table 3. Based on our discussion of the mid-term exam score regression's results, exercise-related involvement and time spent are estimated to have a small positive effect on the final exam score. The estimated effect of a student's average game score on his/her final exam score is 0.13 and significant (p-value < 0.05), larger than that reported in Table 6. This suggests that a student who is a good game player is likely to have a high final exam score. The positive effect of the game score on final exam score, however, may only reflect a student's academic aptitude, rather than the effect of game playing. Indeed, the game score regression in Table 7 has highly insignificant estimates for game-related involvement and time spent. Hence, a student's effort in playing the perfect competition and monopoly games does not materially improve his/her final exam performance. This finding echoes the neutral opinions on the BMOL Game reported in Table 4.

The second check uses an alternative formulation that directly relates a student's scores to his/her involvement and time spent on exercises and games. This formulation comprises four regressions:

Regression 1: Applicable to a student's average exercise score, the first regression is identical to equation (1.a).
Regression 2: This regression is associated with a student's mid-term exam score. It modifies equation (1.b) by replacing the average exercise score variable with the exercise-related binary indicators for involvement and time spent.
Regression 3: This regression explains a student's average game score. It is a variant of equation (1.c), replacing the average exercise score by the exercise-related binary indicators for involvement and time spent.
Regression 4: This regression is for a student's final exam score. It modifies equation (1.d) by replacing the student's average exercise score, mid-term exam score, and average game score with the binary indicators for the student's involvement, average time spent on exercises, and average time spent on games.

Also estimated as a system of SUR with heteroskedastic errors, the four regressions have coefficient estimates for student demographics that closely resemble those shown in Table 6.[12] Table 8 reports the Wald test results in connection to the null hypotheses that a student's involvement and time spent do not affect his/her scores. It shows that the binary indicators for a student's involvement and time spent are statistically significant drivers of his/her average scores for exercises and games. However, they are insignificant for the mid-term and final exam scores. Thus, Table 8 corroborates the BMOL Game's limited effectiveness in improving exam performance. While an increased effort in doing the exercises and playing the games tends to raise a student's exercise and game scores, it has insignificant effects on his/her exam performance.

[12] For brevity, we do not report herein the detailed regression results, which are available from the first author upon request.

Table 8: Wald test results based on the alternative formulation to determine the statistical significance of the effects of involvement and time spent on a student's average exercise score, mid-term exam score, average game score, and final exam score

Null hypothesis	*p*-value
H1: Involvement with and average time spent on exercises do not affect a student's average exercise score	< 0.0001
H2: Involvement with and average time spent on exercises do not affect a student's mid-term exam score	0.9784
H3: Involvement with and average amounts of time spent on exercises and games do not affect a student's average game score	0.0205
H4: Involvement with and average amounts of time spent on exercises and games do not affect a student's final exam score	0.2190

DISCUSSION

While the BMOL Game serves the purpose in providing the contextual environment for students to make decisions for profit maximization using economic concepts learnt in the course, our regression results suggest that game-based-learning via the BMOL Game was only marginally effective in aiding students' exam performance in the microeconomics course in question. However, this is in no way to imply that game-based learning is generally ineffective, but only that the BMOL Game may not be the most appropriate platform for non-English speaking students, notwithstanding the game's documented effectiveness for students elsewhere.[13] As this is the first time using the BMOL Game in the course, there is room for improvement.

To provide a further understanding of our regression results, we recall some of the student views collected in Section III of the survey. These views indicate problems encountered by students, including registration,[14] assessment of games and exercises, the BMOL Game's lengthy student manual, understanding of the exercise questions, and time required to complete the exercises and games.

In response to the information in Table 4 and the above-mentioned student views, we have made extensive changes in the implementation of the BMOL Game during the second semester of the 2015-2016 academic year.[15] These changes include: (i) step-by-step instructions on the screenshot of the registration page for students to follow; (ii) lowering the assessment percentage of games and exercises from a total of 10% in semester 1 to 5% in semester 2, along with providing detailed grading criteria; (iii) additional slides and explanations during lectures to help improve students' understanding of the BMOL Game; (iv) step-by-step guidelines for playing the advanced perfect competition and monopoly games; and (v) reducing the number of exercises from thirteen to six and extending the weekly deadlines for submitting answers.

[13] The BMOL Game's highly positive reviews are available at: http://www.goldsimulations.com/economics-simulation-game/customers-and-reviews.

[14] Some students entered a wrong username or password despite clear written and verbal instructions. The lecturers had to contact BMOL Game technical support to fix the problem.

[15] We plan to conduct a follow-up study of the effectiveness of the BMOL Game after these implementation improvements, along the lines of the present study.

Responding to student feedback, we have also replaced the six advanced games with a Capstone Team Game (CTG) of perfect competition. Under the CTG format, students form teams to compete against each other, enabling each team's members to share knowledge and learn from peers. To help them prepare, students can practice a voluntary trial prior to the CTG's actual implementation.

CONCLUSIONS

To conclude, our first experience of using game-based learning as a complementary learning tool in a microeconomics course indicates mixed findings on the BMOL Game's effectiveness in improving students' learning outcomes measured by exam performance. While the student survey results reveal possible improvements, subsequent discussions with the BMOL Game's designer and experts met by the first author in 2016 at teaching workshops and a conference in China affirm that an education game's success critically depends on how an instructor implements game-based learning.

Based on these discussions, we have a series of recommendations for academics interested in using computer games to teach microeconomics to non-business majors. First, teaching staff should provide additional explanations when English proficiency is a learning barrier for students, including the Chinese students in Hong Kong. This is because simply assigning relevant supplemental readings from the student manual is likely to be ineffective in getting the full benefits out of a commercially available English-based microeconomics game for students at the university.[16]

Second, students should have the opportunity to participate in selecting the game for the course. By including student representatives from different regions of origin and programmes and with varying levels of academic performance, the selection process can acknowledge students as key stakeholders whose learning outcomes ultimately determine if the chosen game is effective. Put bluntly, game-based learning is doomed to fail if the selected game is unwelcome and unused by students.

Third, all teaching staff should collaborate to ensure lecturers and tutors can address game-related administrative matters and student questions in a timely manner throughout the semester. In addition, financial support is necessary to hire graduate students to help answer technical questions about the game. A useful analogy is that the success of a newly launched product/service demands good customer relationship management and support.

Fourth, teaching staff should allocate sufficient time to explain the connection between the game's learning objectives and the curriculum content. Asking students to enumerate how the game's learning objectives relate to those of the course will improve their understanding of the game's purpose before they start playing.

Fifth, team games have advantages over individual games, as students can share knowledge and work more efficiently together. Moreover, camaraderie among team members sharpens the competitive focus of game playing, thereby encouraging active participation by all students.

[16] All public universities in Hong Kong use English as the medium of instruction, except for courses like French, Spanish, German, Chinese history, and Chinese literature.

Finally, subject to time and resource availability, teaching staff should assess student performance immediately after the completion of each game, leading to feedback discussions in the next lecture about the game's learning outcomes.

We would be remiss were we to claim that our recommendations could remedy all of the potential pitfalls in the game-based learning of microeconomics or other related fields. Nevertheless, adopting these recommendations is a step in the right direction to advance an integrated approach to game-based learning of microeconomics and other business subjects at a university like the one mentioned in this paper.

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