Journal of Education and Practice www.iiste.org
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.8, No.35, 2017

Gamification for Non-Majors Mathematics: An Innovative Assignment Model

Siow Hoo Leong* Howe Eng Tang
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Sarawak, Malaysia

Abstract
The most important ingredient of the pedagogy for teaching non-majors is getting their engagement. This paper proposes to use gamification to engage non-majors. An innovative game termed as Cover the Hungarian's Zeros is designed to tackle the common weakness of non-majors mathematics in solving the assignment problem using the Hungarian Method. Non-majors mathematics always fail to draw the correct lines to determine the optimality of the solution, which gives two negative implications: (1) revise the opportunity cost wrongly in the subsequent step; (2) arrive at false optimality where optimal assignment cannot be made. The innovative game has been introduced to non-majors from business major. The results show that it works. The engagement from the gamification based teaching innovation also help to improve visual-spatial processing skill.
Keywords: Gamification, Non-majors, Engagement, Hungarian assignment model

1. Introduction

The courses offered to non-majors are normally at low level of the discipline. However, from the perspective of the course instructors, it is sometime more challenging to teach the non-majors for an introductory course than teaching the majors for a more advance course (Sunderg & Dini, 1993; Knight & Smith, 2010). The main reason is that non-majors show low engagement and motivation (Arvidson, 2008; McClanahan & McClanahan, 2002). They are taking the non-major course as a university requirement rather than a variety that builds the discipline literacy or supports their majors and careers. A growing body of literature shows that some works have been done to address the problem. These innovative pedagogies transform traditional "sage on the stage" (King, 1993) lecture to more learner engaging approaches, for instances active learning (McClanahan et al., 2002), learner-centered teaching (Hurney, 2012), discussion-based activities (Fowler, 2012), constructivist-inspired and topic-centered approach (Garcia, Rahman and Klein, 2015), integration of technologies (Baltaci & Peng, 2017), using portfolios on a web-based platform (Fuller, 2017). To teach non-majors mathematics effectively, one of the key general guidelines is draw learners' interest in the course (Grabiner, 2011; Alayont, Karaali & Pehlivan, 2012). Again, the notion behind the guideline is related to learners' engagement. It motivates this paper to propose gamification for the engagement and learning for non-majors mathematics.

Gamification is defined as the use of game mechanics, dynamics, and frameworks to promote desired behaviors (Lee & Hammer, 2011). This paper chooses gamification because it has shown significant effect on learners' motivation and performance as reviewed by Lister (2015). The main objective of introducing gamification in higher education is to engage learner in complex problem spaces, and challenge learners to develop relevant knowledge (Westera, Nadolski, Hummel& Wopereis, 2008). It can be seen as an experiential learning, i.e. learning by doing, that improves learners' engagement (Li, Ochsner, Hall, 2017).

In this paper, a gamification innovation which termed as "Cover the Hungarian's Zeros (CoHZe)" is introduced to non-majors mathematics in learning the topic of Hungarian assignment model (Tulsian & Pandey, 2005; Kuhn, 2012). There are four main steps in solving assignment model by using the Hungarian method: first, obtain the opportunity cost table; second, test the optimality by drawing minimum number of lines to cover all the zeros; third, revise the opportunity cost table if optimality has not reached, and retest the optimality; finally, perform assignment when optimality has reached. Learners always have problem to precisely work out particularly the second step i.e. draw the correct lines to determine the optimality of the solution. There have been a number of methods being introduced in the references for mastering the above skill. However, learners are still confusing while performing the task. At most of the time the number of lines drawn is more than necessary. It may due to the weakness in visual-spatial processing skill. Failure of mastering this skill gives two negative implications: (1) revise the opportunity cost wrongly in the subsequent step; (2) arrive at false optimality where optimality is declared too early but optimal assignment cannot be made. The CoHZe aims to help the learners to master the skill of drawing lines in the Hungarian Method for assignment model. It is motivated by the research finding by AlHassan (2017) where educational game helps to develop visual perception skill. CoHZe is designed based on the concept of engaging learning and building understanding through game. At the end of the lesson, it is expecting the learners to incorporate the features of the game in the Hungarian Method.

The remainder of the paper is organized as follows. Section 2 describes the CoHZe innovation. Section 3 describes the methodology of the study. Section 4 presents the results. Sections 5 and 6 present the discussion and conclusion respectively.

2. The Gamification Innovation of Cover the Hungarian's Zeros (CoHZe)

The proposed Cover the Hungarian's Zeros (CoHZe) is a game mimicking traditional games which do not include commercial products such as board or PlayStation, but require props such as hopscotch or marbles. CoHZe is not a game for individual but played by a team of players. To have more fun, CoHZe can be conducted as team versus team game.

2.1 How to play

Prop:

1) The prop is termed as ZeroScatter Map. To prepare the prop, draw a diagram of *n* x *n* dimensions on the ground. For illustration purpose and ease of explanation in the following steps, a ZeroScatter Map of 4 x 4 dimensions is considered. Write "zeros" on certain boxes. An example of the ZeroScatter Map is shown in Figure 1.

0	0		0
0			
0			
	0	0	

Figure 1. Prop of the game. The ZeroScatter Map

Number of players:

It depends on the dimensions of the prop. For a *n* x *n* prop, *n* + *n* players is needed for each team.

Rule:

1) One player is stationed in each row and column respectively. The players stationed in each row are the "Workers", whereas the players stationed in each column are the "Negotiator". It is illustrated in Figure 2.

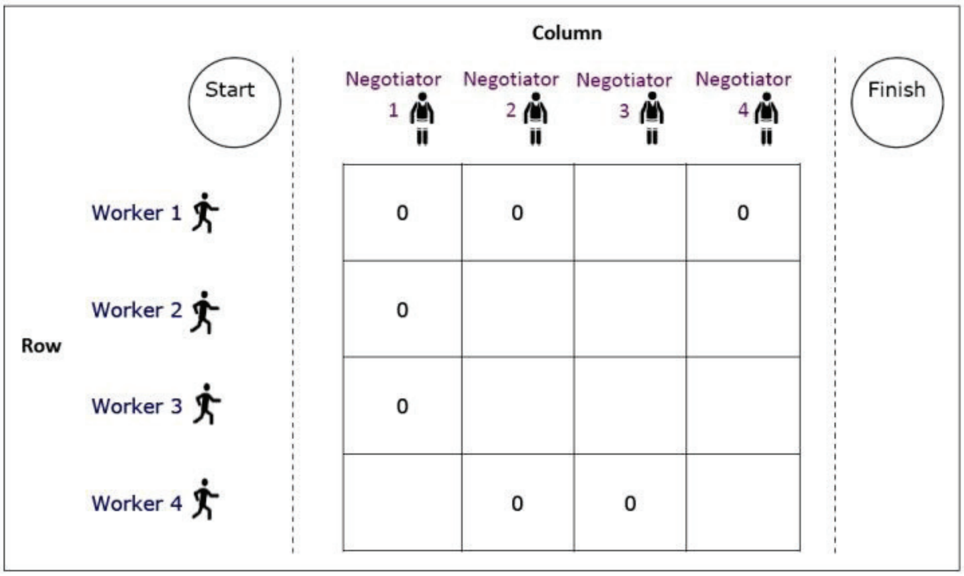

Figure 2. Set up of the game.

2) Each row is the track for the respective Worker. For example, Worker 1 is only allowed to walk within row 1, Worker 2 is only allowed to walk within row 2 and so on.
3) Each column is under the supervision of the respective Negotiator. For example, Negotiator 1 supervises column 1, Negotiator 2 supervises column 2 and so on.
4) The Workers are given the following tasks:
   a) to walk from the starting line to the finishing line, and then put up their hands. However, a Worker can only perform the task if he owns at least a "zero" to himself. The definition of "ownership" can be defined in two ways:
      i) priority ownership: there is only one "zero" in a particular column and that "zero" is on his track row. For example, in Figure 2, Worker 1 priority owns the "zero" at box-14, and Worker 4 owns the "zero" at box-43.
      ii) subsequent ownership: cancel out the track row of Workers who already owned "zero" from the priority ownership stage, if there is only one "zero" in a particular column and that "zero" is on his track row. For example, in Figure 3, after canceling out the priority owner of Worker 1, now Worker 4 subsequent owns both "zeros" at box-42 and box-43.
   b) to stand at the original position near the starting line if the Worker does not own any "zero" as mentioned above.

5) Once the Worker of the respective row put up his hand, that row will be cancelled out. When the process is completed for all the qualified Workers, then it is time for the Negotiators to play their roles. A Negotiator is given the task to raise his hand if two or more "zeros" at the column under his supervision (after the row cancelling process) cannot be owned by any Worker. For example, in Figure 3, only Negotiator 1 has to put up his hand. Workers 2 and 3 need negotiation because they cannot own any "zero" yet from column 1.
6) The opponent team is then check if the Workers and the Negotiators put up the hand correctly.
7) The turn of the opponent team to play.
8) If both teams perform hand raise correctly, it is a draw game. Otherwise, the team that performs correctly is the winner.

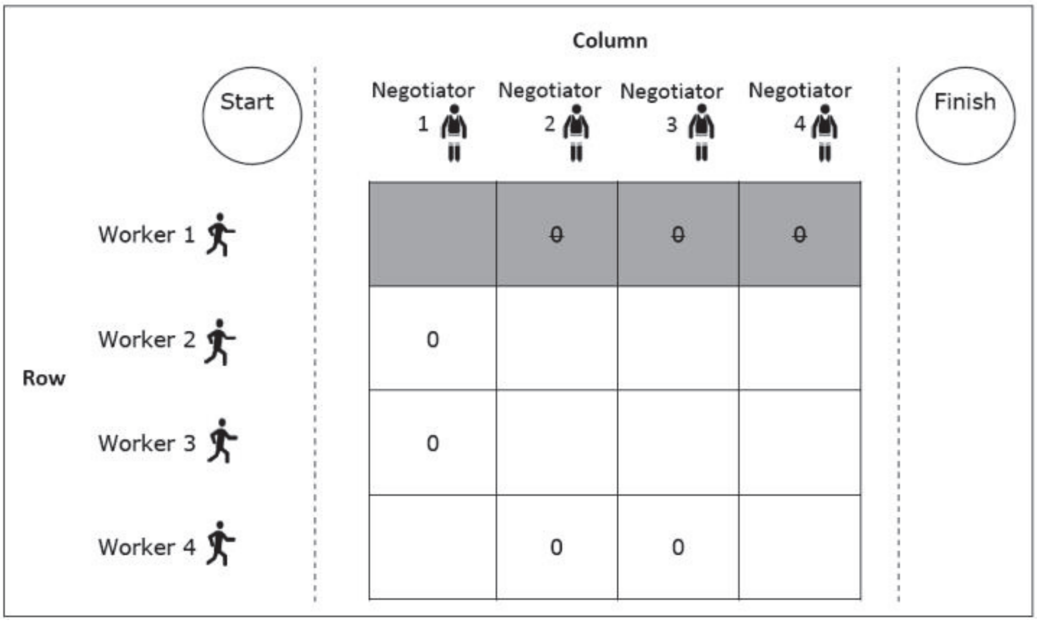

Figure 3. Explanation of subsequent belonging for Worker 4.

Relate game to Hungarian Method

Workers who raise the hands are asked to draw lines on the respective rows, and negotiators who raise hands are asked to draw lines on the respective columns. Learners are asked to comment on what they can see. It is expecting the learners to tell that all the zeros have been covered by the lines drawn! The conclusion is then made that the number of lines drawn by this way to cover all the zeros is minimum.

3. Methodology

3.1 Sample

The sample of this study is 28 non-majors mathematics from programs of International Business, Finance and Marketing, who registered the course of Quantitative Analysis. They are the freshmen of the bachelor degree programs but are placed at second year after credit transferred. The Quantitative Analysis course is the only mathematics course in their program curriculum.

3.2 Instrument

An instrument consists of ten ZeroScatter Maps is used to capture the non-major learners' skill to cover zeros with minimum number of lines. It is developed with considering the common weakness of learners in the topic from the past semesters. The items are a mixture of easy and difficult levels. The same set of instrument is used for pre and post tests.

3.3 Procedure

The procedure to experiment the impact of the game is as follows:

- Before teaching the assignment model, the instrument is distributed to the learners, and 10 minutes are given to settle all the 10 items as per instructed.
- Due to some constraints, the game is only played in the classroom with some minor modifications in the set up:
  - Arrange the tables in the classroom to form the ZeroScatter Map instead of drawing it on the ground.
  - Represent each box of the map by a table.
  - Place the drinking bottles on the tables instead of drawing "zeros" in the boxes. Each drinking bottle represents a "zero".

   - Separate each row of tables by a walk path so that learners who play role as "Workers" in the game can walk to the finishing line if they fulfilled the conditions mentioned in the rules of the game.
- Learners are briefed on the rules of the game.
- Due to time constraints, only two games are played.
- Conduct post-test using the same instrument as pre-test.

4. Result

The impact of the game is analyzed by dividing the non-majors mathematics into three groups according to their scores in the pre-test. Every correct answer in pre and post test is given 1 mark. Those non-majors score 1 to 3 marks in the pre-test are considered as low performers in drawing minimum number of lines to cover all the zeros, score 4 to 6 marks are middle performers, and score 7 to 10 marks are high performers. Table 1 shows the descriptive statistics of the three groups of performers for pre-test. It can be seen that most of the non-majors are high performers. However, only 3 out of 20 of these high performers score full marks in the pre-test.

Table 1. Descriptive statistics for pre-test.

	Category of performers		
	Low	Middle	High
Number of learners	3	5	20
Mean scores	2.33	5.20	8.80
Standard deviation	0.58	0.84	0.83

When the score changes or score difference between pre-test and post-test of the three groups are compared as shown in Figure 4, it is found that the middle performer group shows the highest change with a median score of 3.50 marks. The mean score changes for the low, middle and high performer groups are 1.67, 3.40, and 0.60 marks respectively.

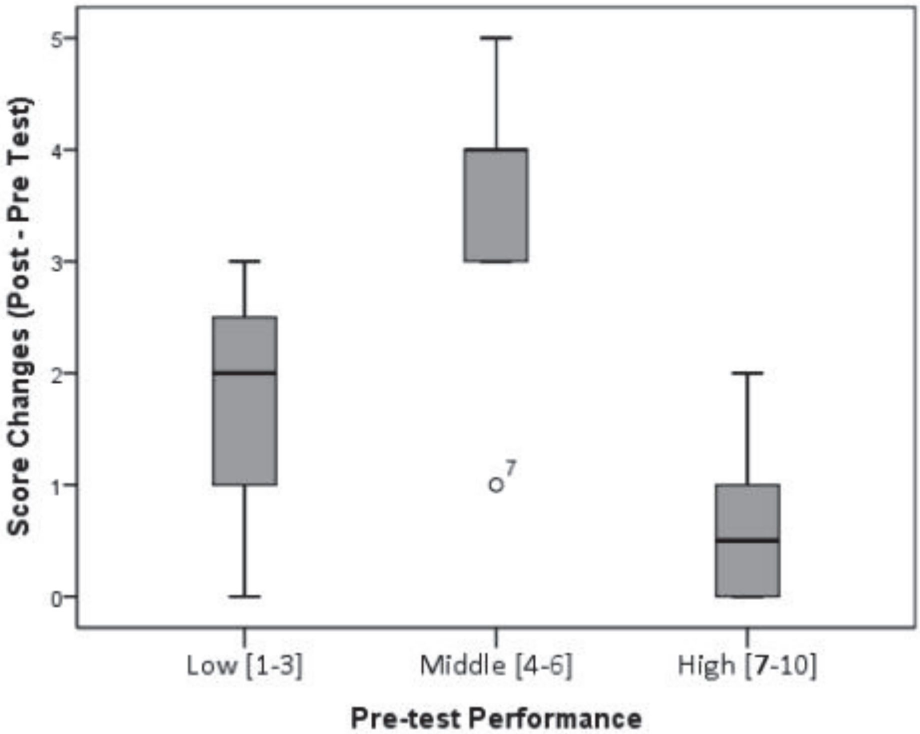

Figure 4. Score changes from pre-test to post-test for the three performer groups.

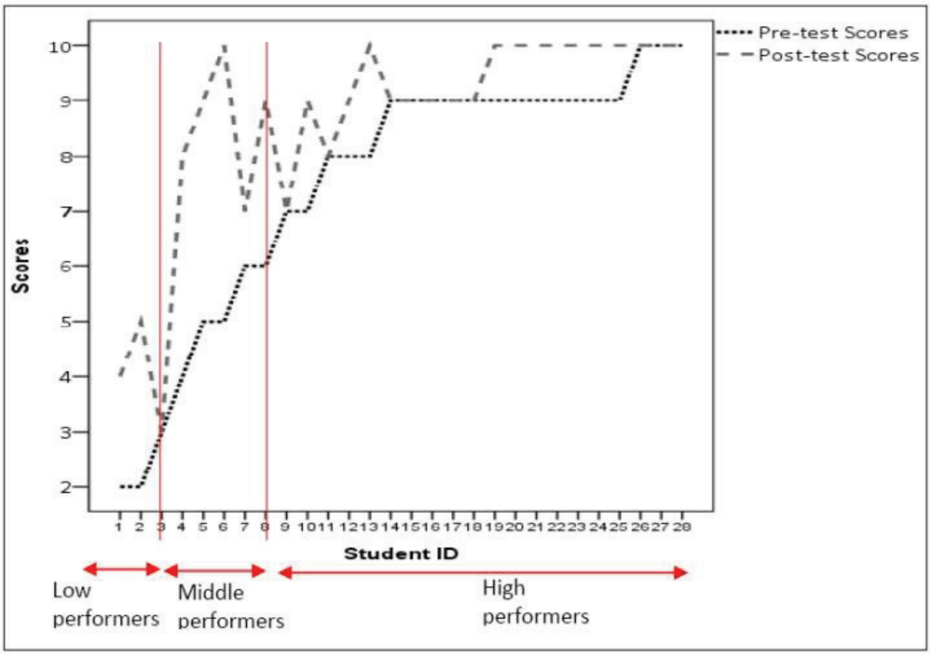

Figure 5. Pre and post tests scores for all the non-major learners.

Further refine analysis is carried out for the scores of pre and post tests for all the learners as shown in Figure 5. Special attention is paid to the high performers. It is found that the number of non-majors who score full marks has been increased from 3 in the pre-test to 10 in the post-test.

5. Discussion

Overall, the scores obtained by the non-majors mathematics in the post-test are better than the pre-test. It implies that the proposed game helps to improve the skill of drawing the minimum number of lines needed to cover all the zeros. However, 57% of the non-majors are not able to score full marks. They have not totally mastered the above skill yet. As the game is played only twice due to time constraint, the impact of the game may not take place yet for some of the non-majors. It is believe that if the game can be played more frequent, the impact will be more obvious.

The results show that the proposed Cover the Hungarian's Zeros game works. To investigate the reasons behind the success, this paper hypothesizes the following statements to be further tested with more empirical studies:

- Remembering rules of game is easier than remembering formal steps of a method, especially when the non-majors have chance to experience the game.
- Learning under game mode promotes interest among the non-major learners and engage them better. Therefore, it provides a better absorbance for new knowledge.
- Gamification promotes engagement, which may help to improve visual-spatial processing skill too.
- Game is also an appropriate method to introduce new concept if it is properly designed, on top of its role as an effective method to enhance learning as suggested by a lot of works in the literature.

When the non-majors mathematics are asked for their feedback on the game, the most frequent responses from them are "fun", "easier to cover all the zeros now". It shows that they appreciate the game and learn the skill. The immediate reactions of these non-majors to the game are two-fold. The sporty learners are more willing to move and take part, whereas the quite learners are a bit reluctant to move and more willing to be observers. However, no matter they are the players or observers, they engage themselves in the game, learning the rules and extend the skill to achieve the objective of the lesson.

6. Conclusion

A gamification based innovation is proposed to engage the non-majors mathematics in learning the Hungarian Assignment Model, particularly on drawing the correct lines to determine the optimality of the solution. It is easy to implement as an outdoor game or even in the classroom when some minor modifications are made. The pre and post tests results show that the innovative game works. The result is expected to be more promising if the game is more frequently played during the implementation. This paper suggests that gamification based teaching innovation is effective to engage the non-majors, no matter as players or observer. With such engagement, not only new concept is learned, but also the visual-spatial processing skill is improved. For future work, gamification can be extended from a topic to the whole course to give a more overall picture of the impact of gamification on non-majors course. Another interesting direction is to incorporate new technological revolution in gamification for non-majors learning. The outcomes will provide some insights to the development and redesign of curriculum in higher education to face the challenges of the fourth industrial revolution.

Acknowledgement
The authors thank the reviewers for their comments on an earlier version of this paper.

References
Alayont, F., Karaali, G., & Pehlivan, L. (2012). What Does It Take to Teach Nonmajors Effctively? *FOCUS (newslettr of the Mathematical Association of America), 32*(6), 11-12.
AlHassan, A. A. (2017). The effectiveness of a training program based on educational games to develop visual perception skills in autistic children. *Journal of Education and Practice, 8*(30), 1-13.
Arvidson, P. S. (2008). *Teaching Nonmajors: Advice for Liberal Arts Professors*. New York: Suny Press.
Baltaci, K., & Peng, A. S. (2017). *Improving Non-Electrical Engineering Student Engagement and Learning in Introductory Electronics Course through New Technologies.* Paper presented at the 2017 ASEE Annual Conference & Exposition, Columbus, Ohio.
Fowler, S. R. (2012). Putting students on the hot seat to stimulate interest in biology in non-science majors. *The American Biology Teacher, 74*(6), 410-412.
Fuller, K. (2017). Beyong reflection: Using ePortfolios for formative assessment to improve student engagement in non-majors introductory science. *The American Biology Teacher, 79*(6), 442-449.
Garcia, R., Rahman, A., & Klein, J. G. (2015). Engaging non-science majors in biology, one disease at a time. *The American Biology Teacher, 77*(3), 178-183.
Grabiner, J. (2011). How to teach your own liberal arts mathematics. *Journal of Humanistic Mathematics, 1*(1), 101-118.
Hurney, C. A. (2012). Learner-centered teaching in nonmajors introductory biology: The impact of giving students choices. *Journal of Microbiology and Biology Education, 13*(2), 133-141.
King, A. (1993). From sage on the stage to guide on the side. *College Teaching, 4*(4), 30-35.
Knight, J. K., & Smith, M. K. (2010). Different but equal? How nonmajors and majors approach and learn genetics. *CBE Life Sciences Education, 9*, 34-44.
Kuhn, H. W. (2012). A tale of three eras: The discovery and rediscovery of the Hungarian Method. *European Journal of Operational Research, 219*(3), 641-651.
Lee, J. J., & Hammer, J. (2011). Gamification in education: What, how, why bother? *Academic Exchange Quarterly, 15*(2), 1-5.
Li, H., Ochsner, A., & Hall, W. (2017). Application of experiential learning to improve student engagement and experience in a mechanical engineering course. *European Journal of Engineering Education*, 1-11.
Lister, M. C. (2015). Gamification: The effect on student motivation and performance at the post-secondary level. *Issues and Trends in Educational Technology, 3*(2), 1-22.
McClanahan, E. B., & McClanahan, L. L. (2002). Active learning in a non-majors biology class: Lesson learned. *College Teaching, 50*(3), 92-96.
Sundberg, M. D., & Dini, M. L. (1993). Majors vs nonmajors: Is there a difference? *Journal of College Science Teaching, 22*(5), 299-304.
Tulsian, P. C., & Pandey, V. (2005). *Quantitative Techniques: Theory and Problems*. Delhi: Pearson Education.
Westera, W., Nadolski, R. J., Hummel, H. G. K., & Wopereis, I. G. J. H. (2008). Serious games for higher education: A framework for reducing design complexity. *Journal of Computer Assisted Learning, 24*(5), 420-432.