Digital Game Based Learning Tools: An Analytic Hierarchy Process (AHP) in Macroeconomics at a Tertiary Education Level

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Abstract

Learning economics can be challenging for most tertiary education students. The main issues in learning economics are a low visualization skills and difficulty memorizing, leading to the inability to comprehend the economics concept and its application. Therefore, this paper determines the criteria and priority used by tertiary education students in choosing digital game-based learning tools in macroeconomics. This study administered a pair-wise comparison survey to 72 tertiary education students in UiTM Perak Branch Tapah Campus. Their judgements were then analysed by a multi-criteria decision-making method, the Analytical Hierarchy Process (AHP). Three main criteria consisted of 'Environment, Motivation and Persuasion Factors' were identified, which had five sub-criteria each. The results found that 'Learner Focus', 'Negotiation', 'Autonomy', 'Compatibility' and 'Prior Knowledge' sub-criteria are the top five priorities in choosing DGBL tools. Thus, prioritising on these criteria will ensure high usage of DGBL tools and high students' academic performance in the future.

Keywords:DGBL, digital game based learning tools, macroeconomics games, economics, tertiary education students, decision making, priorities Analytic Hierarchy Process, AHP

1. Introduction

Learning economics can be challenging for most students at a tertiary education level especially during pandemic and endemic Covid 19. Johari et al. (2018) stated that the main issues in learning economics are a low level of visualization skills and difficulty memorizing, leading to the inability to comprehend the economics concept and its application. Thus, Noviani (2021) suggested that searching for teaching materials and media from internet sources can overcome students' difficulties in learning economics. Gyöngyösi Wiersum (2013) has indicated that teaching and learning through games and activities are of importance to the teaching profession. Lopez-Fernandez (2021) also specified that educational games can create enjoyable learning environment for students, thus improving their learning abilities. Thus, it demonstrates that an enjoyable learning environment for economics has the potential to improve students' academic abilities.

By the advancement of information and communication technology (ICT), the ludic method of digital game-based learning has developed, making the learner an active participant as opposed to only an observer in the virtual and physical learning environment. It is an electronic simulation tool that can boost motivation and learner engagement while also increasing the effectiveness of instruction. Students' knowledge construction, the acquisition of new abilities, and the formation of new attitudes can all benefit from the inclusion of this instructional technology in the teaching and learning process. Digital Game Based Learning (DGBL) is a subset of serious games that combines educational content with computer games (Prensky, 2001a). In addition, DGBL uses cutting-edge tools that are widely acknowledged to have a significant potential to promote and encourage active learning, problem-solving, and communication while offering a setting that embraces practice and learning through failure. Students' learning motivation (Su, 2016; Lin et al., 2018),

learning performance (Lin et al., 2018), cognitive load (Su, 2016; Chen and Huang, 2020), and anxiety (Su, 2016) could be enhanced by digital game-based learning.

With the rapidly changing world, it is important to adapt macroeconomic course with digital game-based learning. Previous studies have explored digital game-based learning only in different subjects, such as Sciences (Chen, 2019), English (Yang and Chen, 2020), Maths (Hung et al., 2014; Deng et al., 2020), and STEAM (Chen and Huang, 2020). Additionally, numerous studies have been conducted on the impact, efficacy, and efficiency of digital game-based learning, but there is a lack of research focus on the criteria and priorities used by students in higher education to select DGBL tools. Besides, few Analytic Hierarchy Process (AHP) evaluations exist in research on digital game-based learning. Thereby, the research objective is to determine the criteria and priority used by tertiary education students in choosing digital game-based learning tools in macroeconomics. The research questions are:

i. What are the criteria and priorities used by higher education students in choosing digital game-based learning tools in macroeconomics?
ii. What is the priority for each criterion used in selecting digital game-based learning tools in macroeconomics?

2. Literature Review

Computer-Supported Collaborative Learning (CSCL) theory emphasizes the significance of collaboration among learners working toward a common goal. To attain the goal, skilful planning, coordination, and implementation of curriculum and technology are required (Koschman 1996; Barbara, 1998; Stahl, Koschmann, & Suthers, 2006). CSCL incorporates the principles of social-constructivist, situated learning, and cognitivist learning theories, emphasizing that knowledge is the result of learners interacting with one another, sharing knowledge, and individually and collectively constructing knowledge (Resta &Laferrière, 2007). In addition, environment, motivation, and persuasion are three essential factors used in this study to select digital game-based learning (DGBL) tools, which are discussed further.

Environment

Jonassen (1999) describes Constructivist Learning Environments (CLES) as a comprehensive set of methods that encourage problem-solving and conceptual growth. CLES, which was initially developed by Taylor et al., enables educators and researchers to track the growth of constructivist learning environments (Taylor & Fraser, 1991). The attitudes of individuals towards a learning environment can be measured by evaluating their responses to four factors: negotiation, prior knowledge, autonomy, and focus.

Empirical evidence by Johnson (2019) explored on effectiveness of DGBL towards teaching and learning, and learners' perceptions of Information and Technology (IT). He confirmed that the participants' perceptions of a constructivist learning environment appear to be positive in junior high school level. In addition, if participants see ownership through negotiation, if the environment proves to be more engaging than existing practices, and if learning in the environment produces tangible results, a new learning environment will be easily embraced (Johnson, 2019).

Moreover, Lagrimas & Buenaventura (2023) discovered the level of school culture as perceived by technology and livelihood education students in Davao del Sur, Philippines is elevated, as is their constructivist learning environment. This study concluded that the level of constructivist learning environment is high, indicating learners receive high ratings for their constructivist learning environment, which is an environment where psychological and pedagogical context influence students' attitudes and success and where learning occurs.

Nevertheless, as pointed out by Yeo et al. (2022), the improvement in the learning performance for females surpassed that of males, particularly within the low prior knowledge category. Students with low prior knowledge tended to be more influenced by their environment and peers, leading to diminished focus. This research aims to investigate how gender and prior knowledge influenced the academic achievement and motivation of fifth-grade students in Taiwan.

Digital capability and digital openness have positive effects on the development of digital creativity among high school pupils, according to Nguyen et al. (2023). The relationship between autonomous student learning and digital creativity is moderated by parental and instructor encouragement. Nguyen et al. (2023) propose that digital creativity can be fostered by improving students' ability to use digital devices, their openness to new information sources on the Internet platform, and their autonomous learning with parental and school support. This study investigates the factors that contribute to the development of digital creativity among Vietnamese high school learners.

Wu, Tzeng and Huang (2020) explored and compared the efficacy of digital game-based learning (DGBL) and static e-learning material for Newton's laws of motion on students' learning focus, affective experiences, cognitive load, and academic performance. Comparing DGBL learning to conventional e-learning approaches, this study exposed that the primary benefits of DGBL learning are improved emotional health and enhanced focus.

Motivation

According to Plass et al. (2015), DGBL is predominantly regarded from a motivational perspective, with an emphasis on the ability of games to engage and motivate. He confirmed that motivational theories focus on answering queries that highlight the multiplicity of factors that influence motivation. Johnson, 2019; Deci & Ryan, 2003; Ryan & Deci, 2000 classified Intrinsic Motivation Inventory (IMI) factors such as competence, satisfaction, enjoyment, interest, and autonomy.

Johnson (2019) and Woo (2014) discovered that when DGBL content is used in the classroom, learners are more motivated to engage with it. Yousef et al. (2014) examined the impact of game-based learning on university students' intrinsic and extrinsic motivation levels and found that games improve students' motivation and performance in both academic and soft-skills areas. Additionally, game mechanics analysis demonstrate that online game-based technologies enable learners to learn by motivating them with fun learning environments and prompt feedback. He examined online gamified resources for formative assessment in higher education foreign language classes (Zhyhadlo, 2022). Janowicz (2019) found theoretical and practical implications of using DGBL in higher education and emphasized the significance of understanding and motivating adult learners and involving them in educational innovation co-design.

Empirical study by Orhani (2023) found that a that a game-based educational setting enhances learners' interest and encourages them to investigate and participate in educational activities. The research aim is to provide a description of how digital games can be used to facilitate the teaching and learning of fundamental mathematical concepts. Additionally, Jonker, Vincent, &Wijers, (2008) examined the effects of computer games on problem-solving, as well as on motivation and interest. Numerous research findings parallel it.

Other findings by Orhani (2023) indicate digital computer games can be extremely beneficial in enhancing students' learning and satisfaction of mathematics. It occurs when learners actively "think and evaluate the mathematics embedded in digital games with three factors that are particularly vital in concentrating students' attention on mathematics: student attitudes, support activities, and collaborative play" (Orhani, 2023).

Besides, Fang et al.'s (2022) stated that higher Social Competence score indicates that a child is more joyful, tolerant, socially integrated, tranquil, and willing for cooperation with peers, and demonstrates prosocial behaviour. When working with young children, the results of this study may assist parents and educators in utilising digital learning tools, particularly video games, effectively. In addition, Leonardou et al. (2022) confirmed that participating educators claimed the Multiplication Game (MG) can enhance learners' multiplication skills and deserves a permanent place in the instructional procedure for the purpose of pupils' progress monitoring and self-evaluation as well as a fun way to exercise and develop multiplication skills.

Previous study investigated one prospective method for Minecraft Education by having Norwegian high school students, take notes within the game, followed by a knowledge exam to gauge their memory. Important effects were discovered between enjoying the assigned activity and playing the game, as well as other significant interactions. It's also worth noticing the relationship between motivation to perform well and enjoyment about the activity, which both predicted test scores. Interestingly, the findings point to task enjoyment as a likely mediator of these characteristics (Reynisson, 2023).

According to Papanastasiou (2022), serious games provide several of basic psychological requirements such as autonomy, competence, and relatedness, which result in some reward or complete a certain essential need associated with encouragement.

Persuasion

Persuasion is one of the five main elements in the diffusion of new ideas where its function is to see value in the innovation (Rogers, 2010). According to Rogers (1995), persuasion occurs when a person adopts either a positive or negative attitude toward the innovation. For an innovation to quickly propagate and be adopted, the following factors must be considered: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2010).

Johnson (2019) revealed that participants' perceptions of DGBL appear to be moderately in favour of DGBL (persuasion). The diffusion of a new technology will increase if potential adopters perceive that it is superior to previous innovations, is compatible with existing practices, is simple to understand and use, and produces observable results (Johnson, 2019; Rogers, 2010; and Rogers Everett, 1995). Moreover, Janowicz (2019) discovered the benefits of peer-assisted learning and peer efficacy in promoting and employing DGBL when persuasive message arguments were strong in higher education.

According to Franciosi (2014) & Franciosi (2016), Foreign Language (FL) instructors in Japanese higher education with a research interest in Computer-Assisted Language Learning (CALL) are inclined to have favourable views on the relative advantage and compatibility of role-playing game (RPG)/simulators than instructors with other research interests.

Franciosi (2014) indicates that improving trialability increases the likelihood of adoption. As a result, a diversified set of materials suitable for addressing a wide range of learning/teaching objectives should be developed, with samples made freely available online for educators to experiment with.

Previous studies have primarily concentrated on impact, effects, efficacy, and efficiency of digital game-based learning, neglecting to explore the criteria and priorities used by students in higher education to select DGBL tools. Therefore, this study examines the criteria and priority used by tertiary education students in choosing digital game-based learning tools in macroeconomics to address the gap.

3. Methodology

This paper used Analytical Hierarchy Process (AHP) as a multi criteria decision-making method (MCDM). AHP is one of the Multi Criteria decision-making methods described by Saaty (2012) to derive ratio scales from paired comparisons. In making judgments about the priority of the criteria, there are three steps in AHP that the researcher must follows (Brunelli, 2015). In step 1, the respondents are asked to perform pair-wise comparisons among the criteria. The scale is from 1 to 9, and its definition is described as in Table 1.

Table 1: Saaty's pairwise comparison scale

Intensity of Importance	Definition
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

Source: Saaty (2012)

If there are m criteria to be evaluated, then the respondent has to make $\frac{m(m-2)}{2}$ comparisons. For example, 10 pairs of criteria will be compared if the number of criteria is 5. Suppose criterion 1 is compared with criterion 2. If criterion 1 is 'strong importance' compared to criterion 2, then m_{12} = 5, and m_{21} = $\frac{1}{5}$. All the pair-wise comparisons collected from each respondent were transferred into matrix form, M, where m_{jk} = $\frac{1}{m_{kj}}, k > j$ such as in Figure 1.

$$M = \begin{bmatrix} 1 & m_{12} & \dots & m_{1n} \\ m_{21} & 1 & \dots & m_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ m_{n1} & m_{n2} & \dots & 1 \end{bmatrix}$$

Figure 1: Matrix M

Evidently, one of the major drawbacks of AHP is that the number of pair-wise comparisons increases exponentially as the number of criteria increases. In Step 2, the degree of consistency is then measured by the Consistency Index (CI). Perfect consistency implies a value of zero, but as individuals' judgments are often inconsistent, it is difficult to comply. Therefore, inconsistency up to a certain degree is acceptable in computing pair-wise judgements. The CI for M is calculated as

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

where λ_{max} is the maximum Eigen vector of matrix M. If the consistency ratio, $CR = \frac{CI}{RI} < 0.10$, then the degree of consistency is acceptable, where the random index, RI values are given in Table 2 (Taylor III, 2004).

Table 2: Random Index, RI, Values

Number of criteria, (n)	Random index (RI)
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41

Source: Saaty (2012)

In the third step, the weight for criterion $j, j = 1, 2, \ldots, n,$ for each respondent's evaluation is calculated by using the following formula:

$$w_j = \frac{1}{n}\sum_{k=1}^{n} \frac{m_{jk}}{\sum_{i=1}^{n} m_{ik}} \quad (2)$$

This process is repeated for every criterion considered. Next, the rule for aggregation of judgments in a comparison matrix is to combine the judgments using the geometric mean if a study involves more than one respondent. Ranking of the criteria can then be determined with the weight values. The higher the weight of a criterion the higher its ranking when compared with other criteria. (Saaty &Peniwati, 2007; Saaty & Alexander, 2013). If p respondents were involved in the assessment, the final weight for criteria j is obtained as a geometric mean, that is, by taking the pth root of the product of all p weights of that criterion, as follows:

$$w_j = \sqrt[p]{w_{j(1)} \times \ldots \times w_{j(p)}} \quad (3)$$

Purposive sampling was used as the researcher targeted tertiary education students that have already use DGBL in class for macroeconomics subject throughout their semesters in UiTM Perak Branch Tapah Campus where 72 students were involved in the study. The questionnaires are created through Google Form and distributed online. All the respondents have been properly explained on how to answer the pairwise comparison questionnaire for each criterion involve in this study.

There are three main criteria that were identified, which are environment factors, motivation factors and persuasion factors with 14 'covering criteria', which is the lowest of criteria/sub-criteria. The 14 covering criteria are shown in Table 3.

After the criteria had been identified, each respondent was asked to compare the importance of each criterion to another criterion, and the evaluation was transformed in a matrix as in Figure 1. Then the weights of the criteria would be calculated by using equation (1). All 72 judgments were aggregated by using the geometric mean approach as in equation (3). Table 4 to Table 8 summarised the final weights, consistency ratio and rankings of the three main criteria and each of the five sub-criteria.

Table 3: Educational Pathway Selection Criteria

Environment Factor	Motivation Factor	Persuasion Factor
Autonomy	Autonomy	Compatibility
Learner Focus	Competence	Complexability
Negotiation	Enjoyment	Observability
Prior Knowledge	Inherent Satisfaction	Relative Advantage
-	Interest	Trialability

Source: Johnson, 2019

4. Results and Discussion

4.1 Ranking the Main Criteria of Students in Choosing DGBL

Table 4 shows the main criteria and priorities considered by students in choosing DGBL, where the main criteria groups are compared regarding their importance with respect to choosing DGBL. The CR value obtained was 0.003, and the results were thus accepted. Environment factors had a higher priority yield at 46 per cent, higher than motivation factors and persuasion factors, which yielded 28 per cent and 26 per cent, respectively. The results indicate that students take environment factors into greater consideration (supported by Taylor & Fraser, 1991; Johnson (2019); Lopez-Fernandez, 2021) when choosing DGBL in comparison with the other two factors.

Table 4: Priorities and ranks of the main criteria with respect of students in choosing DGBL tools

	Priorities	**Rank**
Environment Factors	0.45574	1
Motivation Factors	0.28336	2
Persuasion Factors	0.26100	3

Consistency Ratio (C.R.): 0.00304

4.2 Ranking the Sub-Criteria of Students in Choosing DGBL

Table 5 shows the sub-criteria of environment factors, where each pair of sub-criteria is compared regarding their importance with respect to the environment factors criterion. The CR value obtained was 0.013; This value exceeded the suggested value of 0.10 and below, however Ho, Newell, and Walker's (2005) stated that non-expert group responses in AHP surveys could be as high as 0.20, and the results were thus accepted. Learner focus was shown as having the highest priority (supported by Wu et al., 2020) from students when deciding on their DGBL, followed by negotiation, autonomy, and prior knowledge.

Table 5: Priorities and ranks of the sub-criteria with respect to the environment factors of students in choosing DGBL tools

Main Criteria: Environment Factors	**Local Priority**	**Rank**
Autonomy	0.24371	3
Learner Focus	0.30862	1
Negotiation	0.27757	2
Prior Knowledge	0.1701	4

Consistency Ratio (C.R.): 0.13715

Table 6 shows the sub-criteria of motivation factors, where each pair of sub-criteria is compared regarding their importance with respect to the motivation factors criterion. The CR value obtained was 0.06. Here, students chose interest as the most significant component (supported by Jonker, Vincent, &Wijers, 2008; Orhani, 2023) in choosing DGBL. This was followed in importance by autonomy, competence, enjoyment, and inherent satisfaction.

Table 6: Priorities and ranks of the sub-criteria with respect to the motivation factors of students in choosing DGBL tools

Main Criteria: Motivation Factors	**Local Priority**	**Rank**
Autonomy	0.25019	2
Competence	0.2136	3
Enjoyment	0.16256	4
Inherent Satisfaction	0.12295	5
Interest	0.25071	1

Consistency Ratio (C.R.): 0.06978

Interest and autonomy were the two sub-criteria considered most important by students, with more than 50 per cent priority value in comparison with competence, enjoyment, and inherent satisfaction.

Table 7 shows the sub-criteria of persuasion factors, where each pair of sub-criteria is compared regarding their importance with respect to the persuasion factors criterion. The CR value obtained was 0.05. The results further indicate that students looked for compatibility when deciding on DGBL (supported by Franciosi, 2014; Franciosi, 2016) &. Meanwhile, complexability are the second most important sub-criteria, followed by trialability, observability and relative advantage.

Table 7: Priorities and ranks of the sub-criteria with respect to the persuasion factors of students in choosing DGBL tools

Main Criteria: Persuasion Factors	Local Priority	Rank
Compatibility	0.30325	1
Complexability	0.1887	2
Observability	0.16128	4
Relative Advantage	0.16007	5
Trialability	0.18669	3

Consistency Ratio (C.R.): 0.10853

Table 8 shows the judgements given by student respondents, from which AHP derives the priorities for the factors against the three main criteria. The priorities and ranks are shown accordingly. Each of the three main factors was not evaluated directly, as each of their sub-criteria was evaluated on its own.

The results show that learner focus, negotiation, autonomy, compatibility, and prior knowledge were the five most important criteria for students in choosing DGBL, standing at 7.0 per cent, 6.3 per cent, 5.6 per cent, 3.9 per cent and 3.8 per cent, respectively. In contrast, the bottom five criteria were trialability, enjoyment, observability, relative advantage, and inherent satisfaction at 2.4 per cent, 2.3 per cent, 2.1 per cent, 2.0 per cent, and 1.7 per cent, respectively.

Table 8: Priorities and rankings of the covering criteria of students in choosing DGBL tools

Criteria	Global Priority	Rank
Environment Factors:		
Autonomy	0.055533	3
Learner Focus	0.070325	1
Negotiation	0.063249	2
Prior Knowledge	0.038761	5
Motivation Factors:		
Autonomy	0.035434	7
Competence	0.030252	8
Enjoyment	0.023023	11
Inherent Satisfaction	0.017414	14
Interest	0.035508	6
Persuasion Factors:		
Compatibility	0.039575	4
Complexability	0.024626	9
Observability	0.021048	12
Relative Advantage	0.02089	13
Trialability	0.024363	10

5. Conclusion

To adopt the choice strategies and attract students to use DGBL tools, tertiary educational institutions should capitalise on the criteria that tertiary education student has prioritised to further increase the DGBL tools usage rates. For example, based on the finding in this paper, tertiary educational institutions are able to attract students by using DGBL tools that emphasize on students' focus, create an engaging DGBL tools by making the students see ownership through negotiation, give autonomy for students to practice using DGBL in and out of classroom, provide DGBL tools that are compatible with students levels and subjects, while testing them by using DGBL tools on knowledge or lesson that they already been taught off.

The major limitation of this study was that the researcher only focused on small numbers of tertiary educational students in one university. Therefore, there may be an issue in generalization of the multi-criteria selection. The participation of many tertiary educational students is crucial for the findings to be generalised.

This paper only explores the selection process until the second level of AHP hierarchy, which is the sub-criteria in choosing educational pathway. The selection process can later be expanded by adding alternatives such as type of DGBL tools into the AHP hierarchy so that the tertiary educational student can evaluate the alternatives against the criteria that are chosen. By adding pairwise comparing the alternatives with respect to criteria we will be able to see the type of DGBL tools that tertiary educational studentprioritised when choosing their DGBL tools.

In summary, the selection of DGBL tools of tertiary educational student is very much influenced by environment, motivation, and persuasion factors especially in term of students' learner focus, negotiation, autonomy, compatibility, and prior knowledge. Thus, moving forward in increasing DGBL tools usage in tertiary educational institution in Malaysia, tertiary education educators especially those that teaches Economics should be able to take into consideration of all the important factors in creating DGBL tools for students to encourage them to use DGBL in classroom. Prioritising on these criteria will ensure high usage of DGBL tools and subsequently leads to high students' academic performance in the future.

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