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# Designing Computer Games to Teach Finance and Technical Concepts in an Online Learning Context: Potential and Effectiveness

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**Abstract:** Designing computer games to educate students is not a new technique. Not all disciplines, however, embed the same degree of cognitive load, and not all game design approaches are appropriate across contexts. Teaching technical business disciplines, such as finance, using a game imposes specific challenges, especially when the subject is offered online and to students who may not be from relevant technical backgrounds. However, there has only been limited attention concerning the use of game-based learning (GBL) for teaching finance at the higher education level, especially when delivered online. This article explores the potential of GBL to teach finance at an Australian university. We further present the outcomes of a survey of students' experiences concerning the unique business simulation tool. The results reveal that while a game-based intervention can positively affect students' learning in a technical discipline, such as finance, the design also needs to be such that the players can relate the experience to learning goals and practical needs for satisfactory outcomes. A defining aspect of this research is using Bayesian analysis, capable of gaining insights irrespective of sample size, yet not widely used in the higher education research area in favour of the frequentist analysis. Bayesian analysis shows a high probability of the educational game achieving positive or satisfactory ratings. Further, two aspects of a game—functionalities and usability and perception of impact—are particularly noted to influence the game's overall rating. Overall, the outcomes from this research call for careful consideration of the learners' requirements and capability towards ensuring an enjoyable outcome rather than just focusing on a game's content or context.

**Keywords:** game-based learning (GBL); Bayesian analysis; finance; higher education

**MSC:** 62F15; 91-10



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## 1. Introduction

Designing computer games to teach concepts is nothing new. A plethora of research focuses on adopting computer and digital games and simulation environments to positively impact students' learning across disciplines in the tertiary education context. Kucukkal and Kahveci [1], for example, explore the potential of a board-based game in teaching physical chemistry at a university. Wood and Donnelly-Hermosillo [2] note that students prefer game-based learning (GBL) over study guides when exploring a game to teach chemistry. A further study finds that GBL can increase students' enjoyment in undergraduate math and science courses, concerning which, students often feel anxious [3]. Birt et al. [4] investigate the potential of mobile-based simulation within a mixed-reality environment for medical science courses and highlight that such a system can enhance

students' skills. Research has found computer GBL also effective for teaching undergraduate programming subjects [5].

To what extent may a GBL environment be received positively by business discipline students within an online learning context, especially since they may or may not be tech-savvy and used to such technology-based learning as in other disciplines?

Based on a research project conducted at a multi-campus Australian university, this article addresses this research question and investigates the potential of GBL for teaching finance. In particular, the research aims to assess whether GBL can assist undergraduate finance students to better conceptualise corporate finance concepts, which is essential for them to undertake professional roles.

## 2. Study Background

Understanding how teaching finance and its context differs from other disciplines is essential to realise the objective of this article. Research suggests that teaching finance using traditional means does not prepare students for real-world business problems [6]. Instead, incorporating ill-defined problems, as regularly encountered by finance professionals, can develop the critical thinking skills required by students in the discipline [6]. Research further highlights that digital games can create an engaging learning environment and develop skills to solve ill-structured problems [7]. There are also views that educational games can provide a real-world learning experience, which is not possible to achieve by only solving static exercise problems [8].

Contrary to other business disciplines, finance involves considerable mathematics and technical knowledge. Textbooks on finance often lean towards numbers to present problems and emphasise equations and formulae to solve the problems. However, such practices can make underlying concepts difficult to understand, especially if students lack numerical skills [9]. Research further suggests that adopting a finance textbook that is more readable than others does not necessarily have a positive impact on students' learning experience [9]. This implies the need to go beyond traditional textbooks for effective finance delivery.

Another challenge lies in finance subjects—the cognitive load [10,11]. Cognitive load corresponds to the load on memory learners feel when acquiring new information, thereby shaping the learning experience, especially with limitations on the volume of information individuals can process during a learning activity [10,12,13]. There are different variations of the load. Of particular interest is the "intrinsic cognitive load"—the load experienced by learners because of the complexity of the learning material itself [14]. With finance subjects inherently perceived as challenging by many students, especially with the level of mathematical knowledge involved, the intrinsic cognitive load can be considerable, which calls for management. The literature suggests that cognitive load can be reduced and managed by simplifying and segmenting the learning task and synchronising the presentation materials [12,14]. There is also evidence that GBL can provide a more engaged and retained learning experience than non-game-based learning, positively affecting cognitive loads [15]. Thus, designing a game-based environment to teach challenging finance topics makes sense.

There are simulation software tools that allow players to pose in the role of a trader and learn decision making in security markets. An example is a game offered by the Australian Securities Exchange [16]. There are also some studies, which have explored computer games for teaching finance in the higher education context. For example, Lew and Saville [17] explore the potential of Monopoly, a board game, to teach investment decisions and conceptualise behavioural economics. Marriott et al. [18] report using a trading-oriented simulation for a behavioural finance course and the positive experiences perceived by students and tutors. Helliar et al. [19] note that a computer game targeted at teaching portfolio management can engage students towards applying the theories learnt in their finance courses. Further works have studied the use of GBL, including games that are not necessarily simulation or computer based. For instance, Ingram et al. [20]

report simulation games involving groups and both IT and paper resources to teach various financial management concepts, highlighting the positive impacts of including games in the undergraduate finance curriculum. By applying a role-playing classroom-based game, Akimov and Malin [21] reflect on the benefits of such games in teaching challenging finance concepts, such as swap. Relevant research explores a table-top game to teach accounting subjects, including financial management, and notes the promise of such approaches [22,23]. Ortiz-Martínez et al. [24] further highlight that gamification in financial accounting courses may lead to students achieving higher grades.

Compared to other disciplines, explorations of computer GBL in the finance discipline, however, are relatively scant. Further, the teaching context is different across universities, and so also is the student cohort. The context we consider in this article has unique challenges, adding to the already challenging teaching context of finance subjects because of the intrinsic cognitive load.

Students in the considered undergraduate finance subject come from various programmes, including non-business disciplines, and not necessarily from accounting or finance majors. Consequently, their numeracy skills and academic backgrounds vary considerably. Further, with the relevant programmes offered to both domestic and international students, and students in the programme consisting of both high-school graduates and mature professionals, the students also vary concerning professional exposure and expertise. Moreover, many students enrolled in the subject study online, while others study face to face across campuses, and the learning resources are delivered via a learning management system (LMS). Teaching a highly technical subject, such as finance, can be a significant challenge in such an online context of high student diversity.

As Shin [25] notes, a critical factor affecting students' learning experience, especially in a distance education context, is the "transactional presence" level, i.e., the closeness to educators and learning facilities they feel during their higher education undertaking. Thus, simply managing the cognitive load through segmenting or simplifying learning tasks is not enough in such a context, and there is a need to plan digital contents, which enhances the transactional presence between the educator and the students. Additionally, the current generation of students comprises "digitally enhanced" individuals [26] with varying degrees of expectations about the impact of technology on their learning [27]. Students prefer a customised technology-based learning context meeting their personalised learning needs [28]. Thus, for effective teaching of finance in a high student diversity context, as in this research, there is a need to plan the structure of the digital learning environment congruent with the varying capabilities of students. Arguably, digital games customised to each student's capability and interest can make an impact in such a context. Indeed, research suggests that digital games can improve the learning experience, especially if the game is played for fun [29]. Similar works point to the promise of technologies, such as virtual-reality-based design and co-design approaches, in developing educational materials [30–32].

These considerations motivated this project, which explores the possibility of a game-like environment to teach finance and related technical concepts within a high student diversity and online context. The literature considering such a context is largely scant. There remains not only the challenge of developing a digital game that engages students and unravels the complexities of finance concepts excitingly, but at the same time, the game should be fun to play.

A relevant concept is "cognitive apprenticeship" [33], which can form a theoretical basis for incorporating games in teaching finance. Cognitive apprenticeship corresponds to a learning context in which knowledge is transmitted through a curriculum design from the expert to the learner [33]. The expert shows learners the approaches towards solving real-world problems ("modelling") and interactively guides them to solve similar problems ("coaching") [34]. As the learning progresses, the expert's supports ("scaffolding") are gradually withdrawn ("fading"), leaving learners to self-reflect ("reflection") and socially share their approach with justification ("articulation") and explore alternative solutions

("exploration") [34]. Arguably, the traditional textbook-oriented curriculum design for business disciplines, including finance, limits instruction only to modelling and coaching. However, the use of games can go beyond this and encourage reflection and exploration. In higher education delivery, it is typical for instructors to focus on some topics within a certain schedule before moving onto the next topics, which corresponds to the "fading" stage [34] for the covered topics. However, this is also the time when students are left to self-learn and revise the topics. Thus, a game that considers this student need and encourages them to reflect and explore can potentially lead to retained learning.

Additionally, trading-based simulations, as often investigated in the relevant literature or offered by entities such as ASX, may not meet students' learning needs in higher education finance courses. This is because the objective of finance subjects offered in universities is not specifically to train students as practical traders. Instead, the objective is to conceptually clarify to the students the theoretical, further to practical, foundations and mechanisms that shape the financial markets and how a finance professional—whether a trader or a finance manager or a financial planner or some other relevant service provider—can take advantage of the knowledge to gain a competitive edge in their profession. Additionally, many existing games are more of a passive intervention because these simulation strategy games expect players to learn from experience by making mistakes, and the learning is not necessarily directed. Such passive treatment may not appeal to all students.

Overall, a customised education tool can help teach finance, especially in a high student diversity and online context. It is unclear, however, how such tools can be designed to stimulate satisfactory learning. It is further not clear how students may perceive such tools. This article fills this gap, mainly to guide the design of future initiatives in this regard.

## 3. Design of the Software

The logic that underpins the designed game is as follows:

- A player is presented with a series of questions on a finance concept with increasing difficulty. The challenge in the game is to achieve as high a score as possible by answering most questions correctly on first attempt. Players receive points for correct answers. Nevertheless, the fun part is that the game also tries to deduct random points for each incorrect answer on first attempt and awards no point for subsequent attempts. This means a player needs to thoroughly study the relevant concepts to score high points, as otherwise, the game can deduct a random large score. Thus, in planning the game, the view that an effective educational game should be fun to play [29] was considered.
- Careful consideration was also given in developing questions presented through the game interface. Following the cognitive apprenticeship model [34], the game needs to encourage students to explore and engage with the covered concepts, even when there is limited intervention from the lecturer. Thus, the questions presented in the game are highly critically reflective and much different from traditional textbook exercises. In solving the questions, students need to know the concepts, think deeper, understand the meaning and synthesise multiple concepts. Moreover, all questions incorporate random values, and the accuracy of these answers is checked programmatically. Thus, each time a player runs the game, different values appear for the questions, which retains the game's interestingness, as would not be possible with exercises involving static values. Such randomness, in turn, stimulates the various decision-making contexts finance professionals experience in a real-world market and thus potentially leads to retained learning.

Further, the game design considered that a simple but engaging interface is important for effective learning. In this regard, research suggests some heuristics to consider during the design of the interface of an educational game [35]. These include a visualisation that keeps the user informed of game status, using a language that relates to the real world, an interface that allows the user to recover from any erroneous input, having a consistent

look and minimalist design, and providing help and guidance [35]. These suggestions were abided by in the game's interface.

Figure 1 shows two screenshots from the game to clarify the game's design and interface. Notably, while the question type and context are different, the interface was kept consistent across screens. The interface has a minimalist design, shows the game's state, such as the question being answered and the score, and points to documentation. Further, Figure 2, through two different screenshots, describes the way the game calculates points and handles erroneous situations. Finally, Figure 3 shows screens indicating the game's rules and the fun part of beating the game by trying to answer most questions correctly. Detailed documentation of the game and the way to answer the questions were also provided to students.

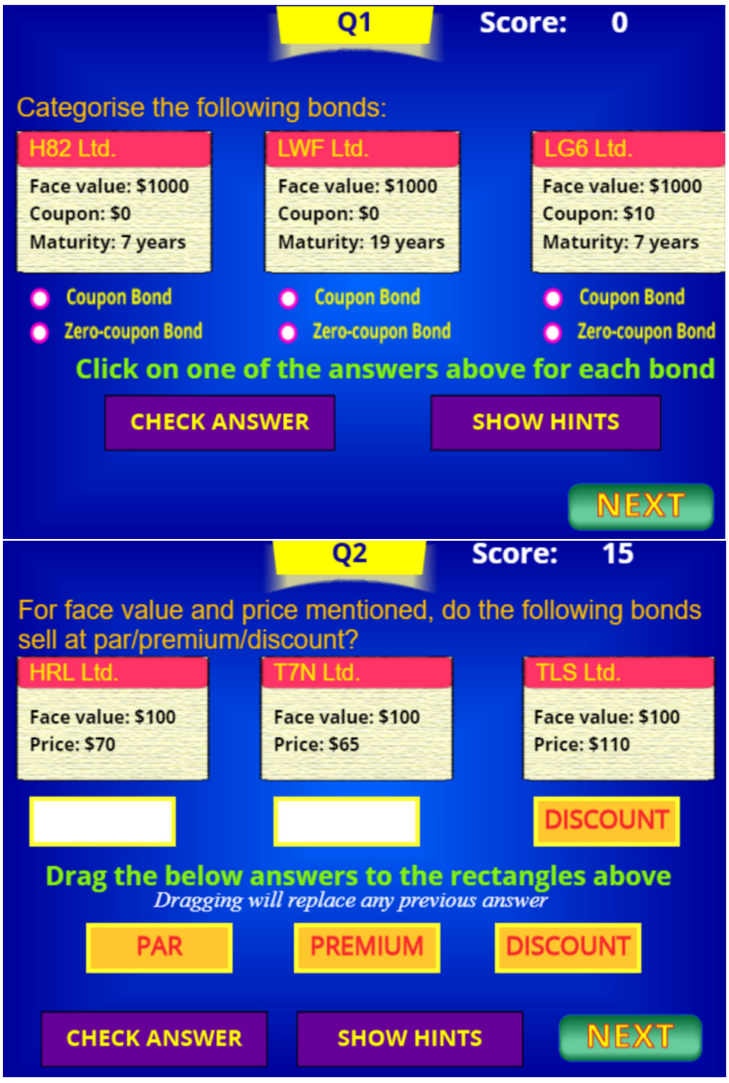


**Figure 1.** Example interface for two questions.

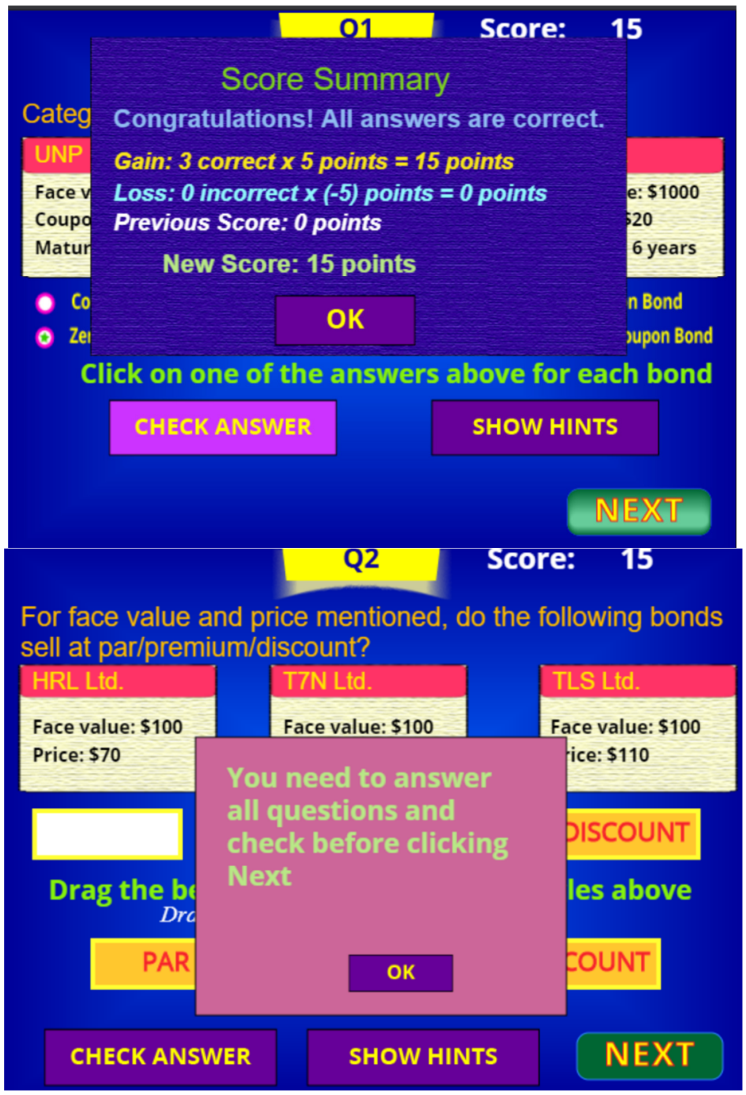


**Figure 2.** Example error screen.

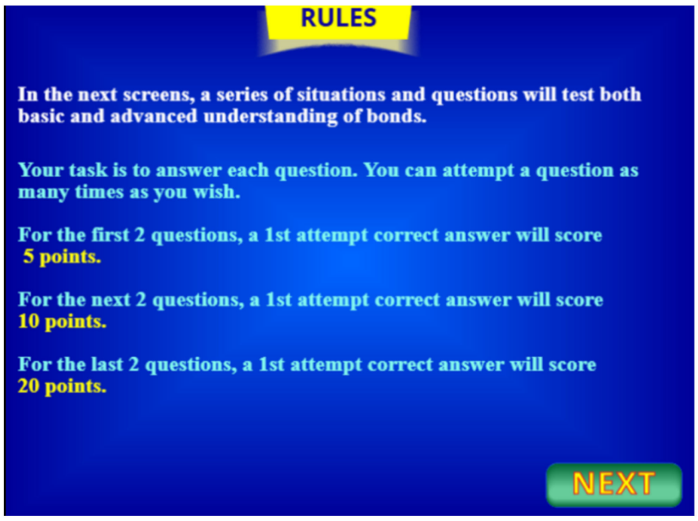


**Figure 3.** *Cont.*

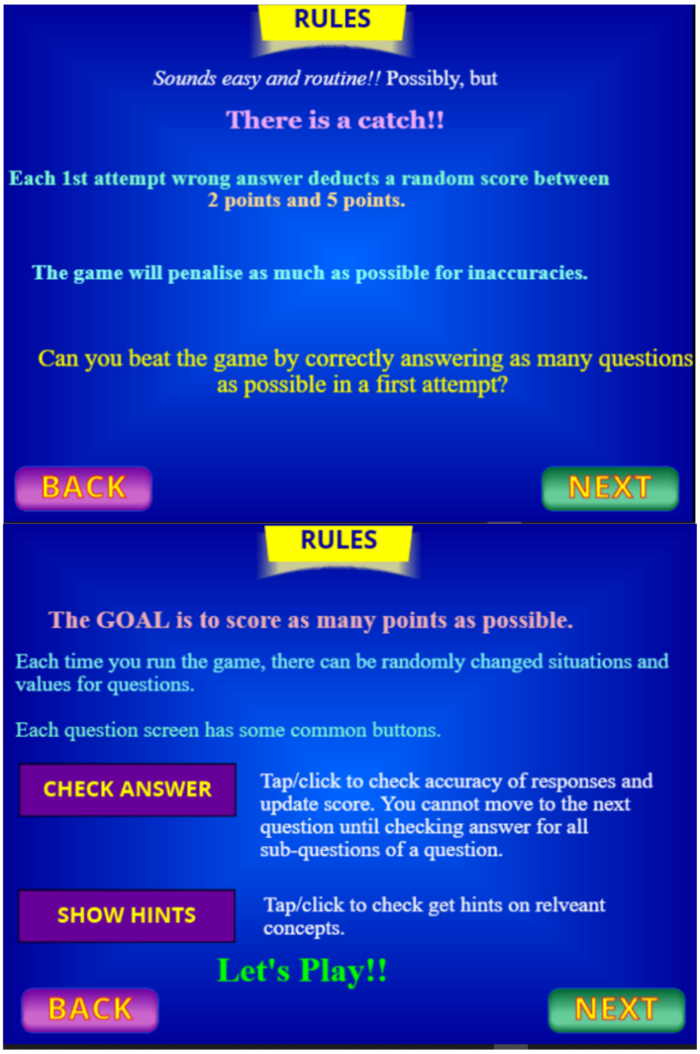


**Figure 3.** Game rules screen.

## 4. Methodology

The game, after being operational, was rolled out over seven semesters between 2020 and 2022 for an undergraduate corporate finance subject taught at an Australian university. Data on the game experience were collected from students voluntarily participating in a survey and self-reporting their experience. The survey questionnaire was motivated by a similar survey for testing the usability and impact of educational technology tools [36–38]. The questionnaire is outlined in Appendix A.

The survey comprised 10 questions, 6 of which covered demographic and background aspects, 2 were related to open-ended comments, and 2 concerned the game experience. The game playing experience was rated across multiple factors, including the game's enjoyability, usability, interface, relevance to learning and the real world, and the impact on learning relevant topics. The open-ended questions sought further student feedback and queried about any re-rating of the game after rating the game, similar to the way applications from modern app stores can be rated and re-rated. The survey was hosted on a SurveyMonkey site, the link thereof being provided as an integrated feature in a game screen and a separate link on Moodle. Students were notified of the game's availability as a learning resource in their respective semesters and were encouraged to complete the survey. Statistical tools were used to analyse the response, as presented in the next section. The open-ended questions were largely not answered—a reason the following section emphasises quantitative analysis only. The data collection and analysis occurred fol-

lowing the project's ethics protocol approved by the university's relevant human research ethics committee.

## 5. Results

### *5.1. Descriptive Statistics*

The following sub-sections illustrate the key results of this research. Not many students left feedback, despite the survey being promoted via email and other means. Many students enrolled in the undergraduate unit are online students who are busy professionals. Arguably, the flexible study patterns, combined with the COVID-19 pandemic and its impacts on various aspects, including a low enrolment size since 2020, explain the low response rate. Further, the game was rolled out as an online and optional educational resource for students enrolled in the respective finance subject. Following the approved ethics protocol, their participation was completely voluntary, and no identifiable information about them was recorded in the system. Thus, the research team could only encourage their participation in the project through general emails, and directed encouragement at the individual level, which may have increased the sample size, was not possible. Nevertheless, there were 12 responses to the survey. Upon investigation, it was noted that one response might not be valid, since the response came in late May 2020, soon after the game was rolled out. However, a technical issue initially affected the game's operation, and the issue was addressed in June 2020. In the rest of this paper, we exclude this single response and consider only the 11 responses that occurred after the game had been fully operational.

Figure 4 shows the semester when the responses to the survey occurred. Although the responses arose across terms, they were all based on the same intervention product, i.e., the same software version covering identical teaching materials. Thus, the results are comparable.

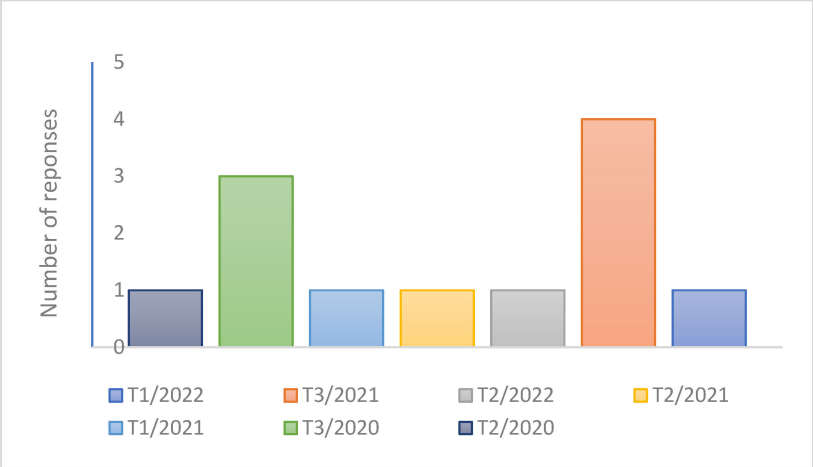


**Figure 4.** Semester when responses occurred.

Figure 5 shows the study status of the survey respondents. Notably, most respondents were online and part-time students, congruent with the unit's enrolment pattern.

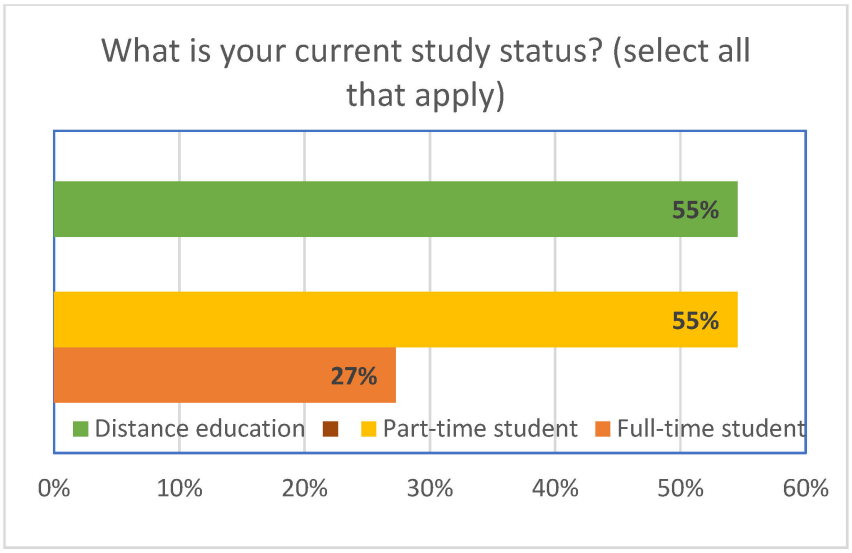


**Figure 5.** Study status of respondents.

Even though the unit is taken as a core and optional unit across disciplines, the respondents mainly stemmed from accounting and financial planning majors (Figure 6).

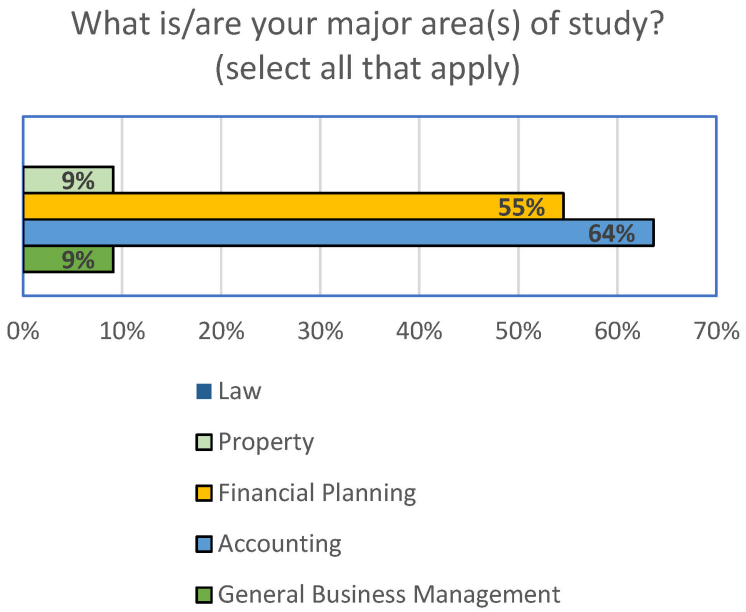


**Figure 6.** The study area of respondents.

Professionally, respondents primarily worked for an organisation full time (Figure 7).

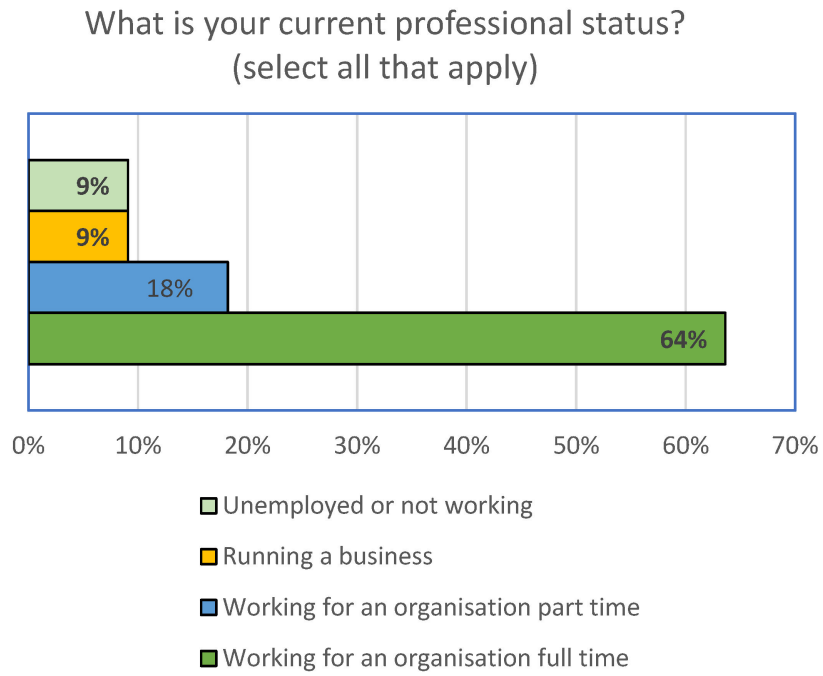


**Figure 7.** Professional status of respondents.

Most respondents were between 25 and 44 years of age (Figure 8). Thus, the respondents corresponded mainly to Gen X and Millennial generations [39].

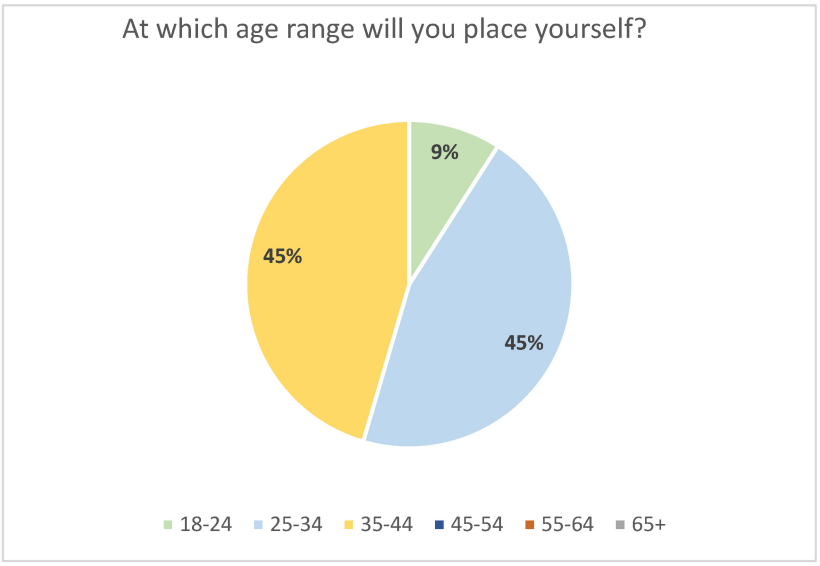


**Figure 8.** Age group of respondents.

The survey aimed to conceptualise respondents' information technology (IT) skills and financial market knowledge, especially to understand if these impact their experience. Interestingly, most respondents considered themselves expert IT users (Figure 9). By contrast, respondents generally did not believe that they had expert knowledge of financial markets, even though most indicated some knowledge in this area (Figure 10).

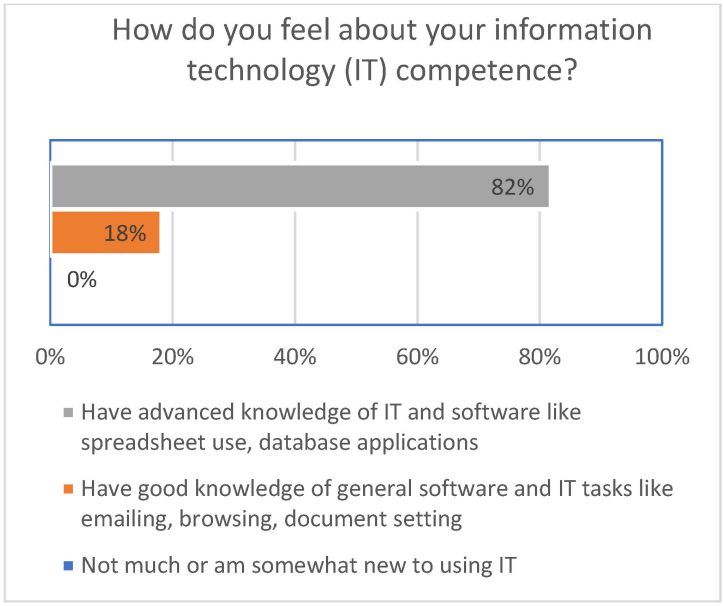


**Figure 9.** Respondents' IT competence.

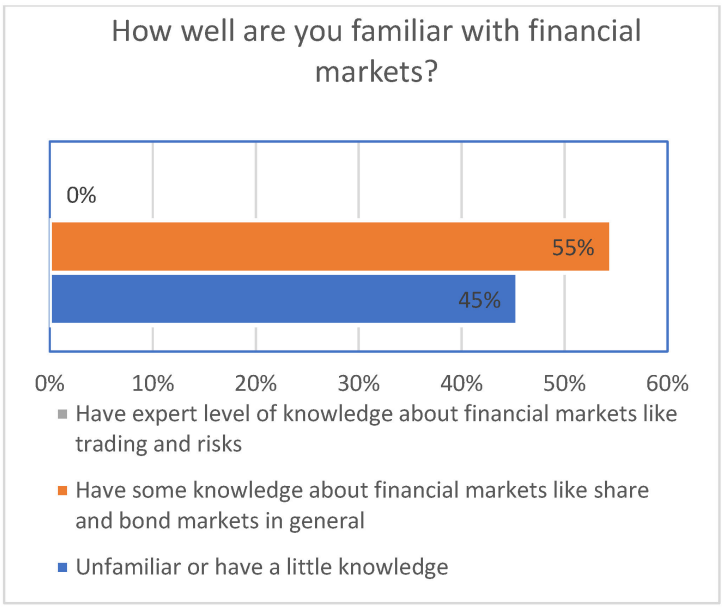


**Figure 10.** Respondents' knowledge of financial markets.

Overall, Figures 4–10 reflect the diversity among students concerning the programme of study, demographic attributes and experiences. The following results illustrate respondents' perceptions of the game experience and its impacts across various aspects.

Figure 11 illustrates that most respondents deemed their game experience, overall, as satisfactory or highly satisfactory. Figure 12 reflects the respondents' rating concerning the game's functionalities and usability. Barring ratings on the visual outlook, ratings on other aspects were largely positive.

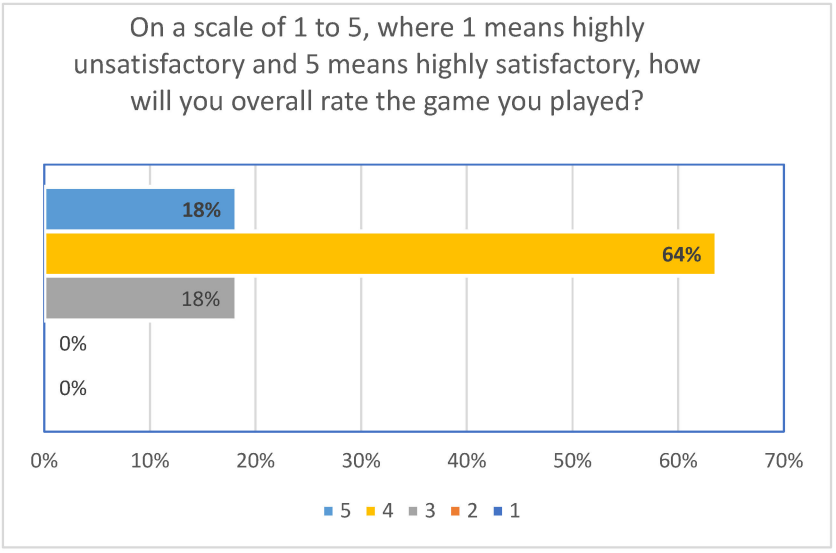


**Figure 11.** Respondents' satisfaction with the overall game.

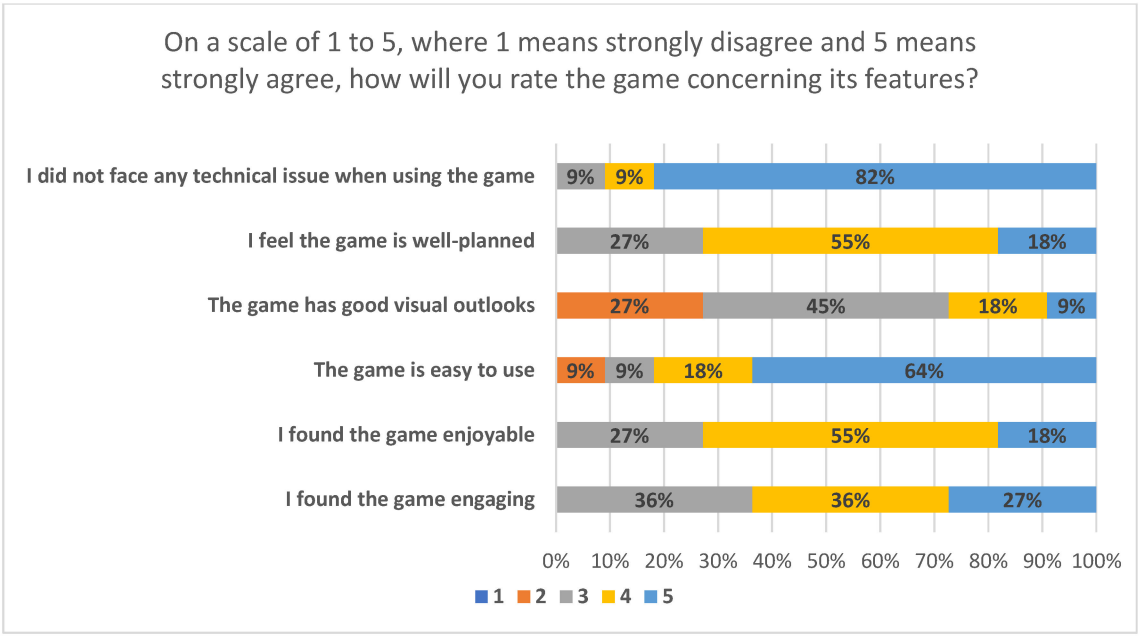


**Figure 12.** Respondents' rating concerning the game's functionalities and usability.

Through its questions within a quiz-like environment, the developed game assesses students' ability to reflect critically and make investment decisions within some contexts. Thus, the survey also queries how students perceive the encountered situations, i.e., game content. Noticeably, although the game attempted to model some real-world situations, the rating concerning this was primarily neutral (Figure 13). However, most respondents deemed GBL better than textual resources and felt it assisted them with assignments (Figure 13). Further, many respondents agreed that the situations bolstered their critical thinking and engagement with the contents (Figure 13).

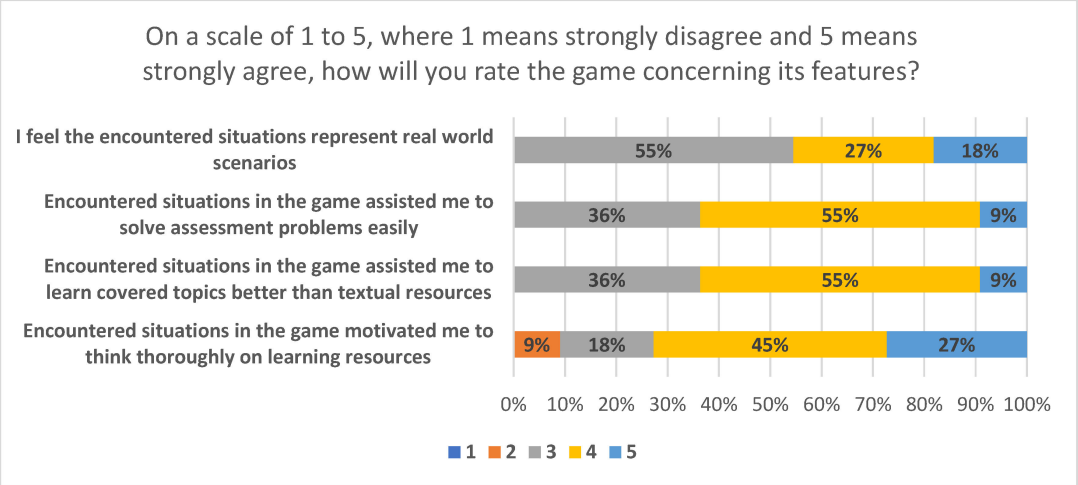


**Figure 13.** Respondents' rating concerning the game's situations (i.e., content).

Finally, Figure 14 highlights the game's impact on students' learning. Notably, a large majority of the respondents agreed that the game supports their learning and professional undertaking. It is the aspect of a memorable experience where the responses were dispersed.

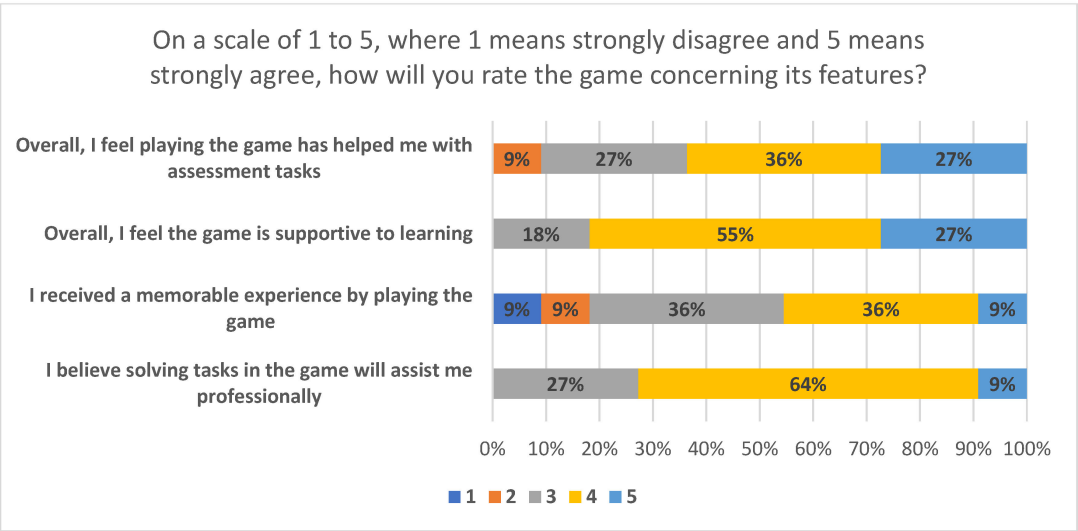


**Figure 14.** Respondents' rating concerning the game's impacts.

It is worth considering the validity and reliability of the survey questionnaire. The questionnaire planned for this project relates to similar questionnaires used by other research works on the perception of educational technologies in the higher education learning context [37,40]. Thus, the survey instrument has "content validity" [41]. Further, Cronbach's alpha can objectively reflect the reliability of survey instruments in conceptualising some measurements [42]. Hence, we determine Cronbach's alpha ($\alpha$) for the 15 Likert scale survey items reflected in Figures 11–14. The $\alpha$ value is 0.931, which implies an "excellent" level of "internal consistency" [42].

### *5.2. Further Analysis Using Bayesian Inference*

It may be argued that the response rate for the project is very low to reach conclusive evidence. Such may be the case if we consider the commonly used frequentist statistics approach. However, the statistics discipline embeds another school of thought—Bayesian statistics. Bayesian statistics tools can make credible inferences even for low sample size,

especially with their approach to model building, which is different from the frequentist school of thought. The frequentist approach emphasises assessing test statistics assuming a null hypothesis to be true unless the observed samples prove otherwise with a reasonable confidence level; a low sample size leads to potential errors and less statistical power in the frequentist school of thought [43]. By contrast, the Bayesian approach considers the probability of various hypotheses and focuses on the likelihood thereof for the observed samples [43]. The underlying statistical concept does not depend on the central limit theorem—a reason it is well applicable for small datasets if a reasonable prior is considered [44]. Indeed, the capability of Bayesian analysis to provide meaningful outcomes for a small sample has been noted in existing research [45–48].

Therefore, we conduct multiple Bayesian analyses on the project's outcome to gain further insights. The higher education literature has primarily focused on the frequentist school of thought. As such, the incorporation of Bayesian analysis in this paper differs from the common trend and may encourage further research using the tools.

Using the Bayesian analysis approach, we first explore how likely the GBL for the business unit, as we designed it, is to be rated positively by random students. In this respect, we model a user (i.e., game player) rating the overall game experience as a Bernoulli trial, expressed by a random discrete variable $y$, with a value of 1 indicating a satisfactory or highly satisfactory rating, and 0 otherwise. Then, the probability of rating can be expressed as a Bernoulli distribution [49]:

$$(y|\theta) = \theta^{y}(1-\theta)^{N-y} \tag{1}$$

where $y\epsilon\{0,1\}$, $N$ is the total number of trials (i.e., total number of samples), and $\theta$ is a parameter, such that $p(y=1|\theta) = \theta$, i.e., $\theta\ \epsilon\ [0,1]$ is the probability value of a positive rating [49].

Bayesian analysis entails incorporating prior knowledge, which is adjusted for posterior probability following the Bayes theorem in the analysis [43,49]. For the context of this research work, the potential prior knowledge is how likely a similar educational game system is to be rated positively. Because the game system used in the business unit was designed as a pilot project, and there is no similar precedent system, we assume $\theta = 0.5$; i.e., we assume the probability of a player rating the experience of playing an educational game as positive or otherwise ($y = 1$ or $y = 0$) is equally likely.

A central aspect of Bayesian analysis is specifying the probability distribution of priors. In this regard, to maintain the conjugate prior property associated with a Bernoulli distribution, we model the prior for the probability of a positive rating via the beta distribution [49]:

$$p(\theta|a,b) = \theta^{(a-1)}(1-\theta)^{b-1}/B(a,b) \tag{2}$$

where $B(a,b)$ is the beta function, with $a,\ b$ as the hyperparameters of the beta function.

The next step is assigning the hyperparameters. Kruschke [49] refers to the central tendency of the beta distribution for assigning the prior values of $a,\ b$. Assuming an effective sample size ($\kappa$) of 20, and the mean of the beta distribution ($\mu$) tends to be 0.5, $a = b = 10$ (please refer to [49,50] for more details). The considered $\mu$ value conceptually implies our prior belief that the likelihood of a similar educational game receiving a positive rating by a sample of participants tends to be 50%, on average.

Next, we use the RStan package [51] in the R statistical computation system [52] to fit the observed data (i.e., survey outcomes comprising the 11 responses) with the assumed Bayesian model. The Bayesian analysis explores the parameter space (in this case, the probability of a positive rating) that fits the data. Table 1 shows the RStan output for the fitted parameter. We note that the Rhat values are 1, implying the convergence of the Bayesian analysis, i.e., the analysis outcomes are valid. The estimated mean of theta ($\theta$) is 0.62—higher than our prior belief concerning a positive rating about the educational game. Further, Figure 15 shows the posterior distribution of $\theta$ along with the 80% credibility intervals. Notably, the interval lies above 50% and extends to about 73%. Thus, at a reasonably

high credibility level, the probability of the educational game achieving a positive rating is above 50%. In other words, participants are more likely to rate the experience of playing a similar educational game as satisfactory or highly satisfactory than give other ratings. This implies the potential for using educational games in business units.

**Table 1.** RStan [51] output for fitting the probability of a positive rating. The analysis entails 4 chains, each with 2000 iterations, 1000 warmup samples. The total post-warmup draws are 4000 samples.

| | **Mean** | **se_Mean** | **sd** | **2.50%** | **25%** | **50%** | **75%** | **97.50%** | **n_eff** | **Rhat** |
|---|---|---|---|---|---|---|---|---|---|---|
| theta | 0.62 | 0 | 0.09 | 0.44 | 0.56 | 0.62 | 0.68 | 0.78 | 1415 | 1 |
| lp__ | −21.24 | 0.02 | 0.77 | −23.44 | −21.42 | −20.94 | −20.75 | −20.69 | 1705 | 1 |

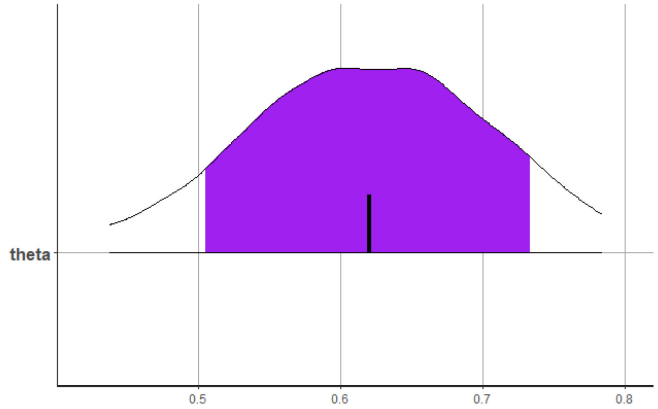


**Figure 15.** Posterior distribution of $\theta$, as generated using RStan [51]. The purple shaded area implies the 80% credibility interval.

In a second analysis, we consider a Bayesian regression model and explore the extent to which an educational game's functionalities and usability, content and the game's players' perception of various impacts, i.e., the game's different aspects, may relate to the overall satisfaction with the game. We consider the following model:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \varepsilon_i. \quad (3)$$

where both $y_i$ and $x_{ji}$-s are dichotomous variables reflecting the overall satisfaction with the game and the overall rating concerning various aspects, respectively.

$y_i \epsilon \{0, 1\}$. is the dependent variable, with a value of 1 indicating a satisfactory or highly satisfactory rating about the overall game and 0 otherwise by a participant (i.e., a game player).

$x_{1i}$, $x_{2i}$ and $x_{3i}$ are the predictor (i.e., independent) variables coded as follows and representing, respectively, the overall rating about three aspects: functionalities and usability (characterised by the items shown in Figure 12); content (conceptualised by the items shown in Figure 13); and the game players' perception of impacts (captured by the items shown in Figure 14). Notably, the survey in this project asked participants to rate the different aspect items via a 5-point Likert scale, with 1 indicating strong disagreement (i.e., negative rating) and 5 indicating strong agreement (i.e., positive rating). Let $r_{jki}$. indicate the rating concerning the $k$-th item of aspect $j$ by a participant $i$, and $\hat{r}_{ji}$ is the average of such rating for aspect $j$ by participant $i$. With $1 \leq r_{jki} \leq 5$ for all $i$, $j$, $k$, $\hat{r}_{ji}$ lies in the interval [0, 5]. We code the numeric $\hat{r}_{ji}$ variables into dichotomous $x_{ji}$ variables. We assume an average rating score concerning an aspect exceeding the value of 3.0 (i.e., neutral rating) implies a positive rating about the aspect, which we represent by the value of 1. An average rating of equal to or less than 3.0 for an aspect, by contrast, implies a negative or neutral rating concerning the aspect by the respective participant, and we represent this

by a value of 0. In other words, $x_{ji} = 1$ if $\hat{r}_{ji} > 3$. and 0 otherwise. In this way, for each participant, we transform the respective Likert-scale responses concerning items covered by the game aspects (functionalities and usability, content and perception of impacts) to dichotomous predictor variables, which form the ($x_{1i}$, $x_{2i}$, $x_{3i}$) predictor variables set.

$\beta_i$-s are coefficients in the regression Model (3), and $\varepsilon$ is the noise.

We subsequently consider the Bayesian regression analysis technique and thereby focus on the potential influence of different game aspects on the game's overall rating. We use the brms R package [53–55] to conduct the analysis and consider the default Gaussian family to model the response variable; this consideration relates to applying a generalised linear regression model. While the response can also be modelled using the binomial distribution with $y\epsilon\{0, 1\}$, we note that because of the small sample size and the consequent impact on the underlying analysis, the Bayesian regression model does not reach convergence. Additionally, with the regression model, we aim to conceptualise how ratings concerning various educational game aspects relate to the game's overall rating, and the focus is not on developing a prediction model. With these in consideration, choosing the Gaussian family makes sense.

Table 2 shows the brms analysis outcomes. As noted, the Rhat values are 1, implying convergence of the model. The outcome shows two aspects as being highly influential in shaping the overall experience of the game: functionalities and usability (associated with the coefficient b1 (i.e., $\beta_1$)) and perception of impact (associated with the coefficient b3 (i.e., $\beta_3$)). The outcome is further visualised in Figure 16. Notably, the coefficients associated with functionalities and usability (b1) and perception of impact (b3) both have density concentrated at values near 0.5, indicating their potential positive impacts on overall game satisfaction. By contrast, the influence of game content (b2) is somewhat neutral, with the 95% confidence interval covering both positive and negative impacts. Thus, for an educational game, within a reasonable credibility interval (95%, in this case), the game's functionalities and usability and the perception players have regarding the game's impact appear to have a notable influence on the overall satisfaction concerning the game.

**Table 2.** Output from Bayesian regression model fitting using the brms R package [53–55], as copied-pasted from the R system with minor customisation. The variables b1, b2 and b3 correspond to $\beta_1$, $\beta_2$ and $\beta_3$ of the model. mu and sigma are the hyperparameters of the Gaussian distribution, respectively, corresponding to the estimate of the response variable $y$ and standard deviation of the estimate (i.e., noise indicated in the model).

| Family: Gaussian | | | | | | | |
|---|---|---|---|---|---|---|---|
| Links: mu = identity; sigma = identity | | | | | | | |
| Draws: 4 chains, each with iteration = 2000; warmup = 1000; thin = 1; | | | | | | | |
| total post-warmup draws = 4000 | | | | | | | |
| Population-Level Effects: | | | | | | | |
| | Estimate | Est. Error | l-95% CI | u-95% CI | Rhat | Bulk_ESS | Tail_ESS |
| Intercept | −0.01 | 0.33 | −0.7 | 0.66 | 1 | 4016 | 2901 |
| b1 | 0.51 | 0.4 | −0.32 | 1.33 | 1 | 2434 | 2320 |
| b2 | 0 | 0.24 | −0.47 | 0.47 | 1 | 2634 | 2116 |
| b3 | 0.5 | 0.29 | −0.12 | 1.09 | 1 | 2413 | 2238 |
| Family-Specific Parameters: | | | | | | | |
| | Estimate | Est. Error | l-95% CI | u-95% CI | Rhat | Bulk_ESS | Tail_ESS |
| sigma | 0.32 | 0.1 | 0.18 | 0.58 | 1 | 1568 | 2205 |

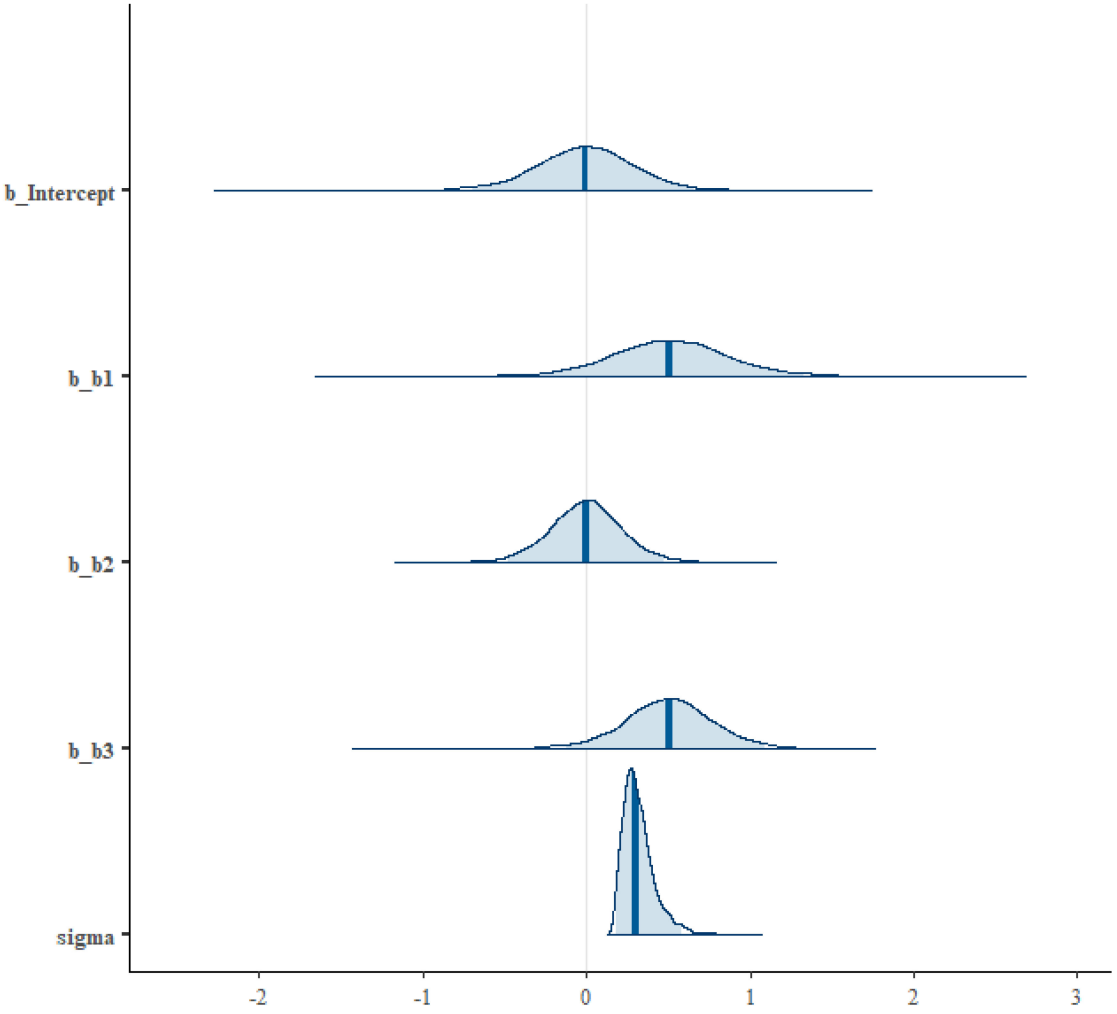


**Figure 16.** Density plot of the fitted regression model, generated using the brms R package [53–55]. The coefficients are labelled with a prefix "b_"; this is due to auto generation by the relevant R function. b_intercept corresponds to $\beta_o$; and b_b1, b_b2 and b_b3, respectively, correspond to $\beta_1$, $\beta_2$. and $\beta_3$ of the model. The shaded blue area indicates the 95% credibility interval.

## 6. Discussion

Overall, the GBL initiative showed promise. Although there have only been 11 valid responses, small size is not uncommon for studies on the effect of GBL, such as 27 [23] and 12 [31] samples in existing works. A defining aspect of this article, however, is also the consideration of Bayesian analysis, which can provide meaningful insights even for a low sample size [46,48], which, to the best of the authors' knowledge, has not been well explored for studying the effect of computer-based GBL in business disciplines. Thus, this article makes an academic contribution in that respect.

The outcomes observed are also interesting. Notably, the game impacted students who played it and responded to the survey. Research suggests three dimensions in an educational game design: users, learning objectives and game mechanism [56]. Arguably, our survey outcomes show that, among these, the emphasis on learning objectives can be specifically important. Of particular interest, despite the game having mixed views about its visual outlook and ability to create a memorable experience, students largely considered it as engaging and relevant to the profession. Further, most respondents identified the game as supportive of learning and the game's situations as causing them to think critically about the learning resources. These outcomes show that, in designing educational games in technical disciplines, such as finance, especially in an online context, an emphasis should

be placed on the learning objective and the relevance of it to the user. As long as users feel that they are learning and benefiting from educational games and can connect the relevance of that learning to their professional or personal development contexts, they are likely to be satisfied despite weaknesses in aesthetics or functionalities.

Indeed, the support behind this also comes from the relevant literature on authentic learning. As outlined by Herrington et al. [57], while there are various views on what constitutes authentic learning for students, such learning has some notable characteristics. The context needs to be motivative and purposeful concerning the learning goals; the learning tasks should have relevance to real-world situations and encourage students to reflect on the learning materials [57]. Arguably, the designed game embodies these characteristics. The investment decision situations that students confront in the game relate to financial decision-making situations that respective professionals face in the industry. Simultaneously, the game incorporates challenges that are not simply mechanical assessments of knowledge but also require students to think critically about multiple concepts learnt on the respective topic and synthesise them based on that reflection. This inherent mental challenge, which, arguably, corresponds to increasing germane cognitive load while managing extraneous cognitive load [11,13] through a game-based interactive environment [15], potentially explains the positive ratings received in the survey.

Most respondents also positively perceived the game compared to textual resources. As highlighted earlier, there is evidence that students struggle with mathematical finance textbooks, and simply choosing one book over others does not necessarily positively impact students' learning experience [9]. Research has also noted the positive impacts of educational games on students' learning [15,29,58]. Arguably, the survey outcomes corroborate this view.

The demographic analysis also reflects interesting outcomes. As detailed earlier, a large majority of respondents to the survey identified themselves within the 25–44 age range; they belonged mainly to the Gen X and Millennial generation [39]. Research notes that gamification in the curriculum and simulation can appeal to the Millennial generation, especially with members of that generation being often more accustomed to technologies [59]. Research further highlights similarities between Gen X and Millennials concerning IT usage and knowledge [60]. Further, the Millennial generation and Gen X embrace technologies for entertainment and information-seeking purposes [61]. Potentially, this explains the designed game's appeal to Gen X and Millennial respondents, especially with the game attempting to introduce fun into the learning process while also educating players about the concepts relevant in financial decision-making scenarios. Coleman and Money [62] recommend that designs of educational games should align with research on students' learning. Arguably, the outcomes of this project reflect this view. When incorporating games in a business subject in a higher education context with high student diversity, such gamification is likely to attract primarily Gen X, Millennial and later generation students; however, attracting senior students at senior age levels can be challenging. With senior students often pursuing business degrees for career changes or upskilling, the gamification of the business curriculum may need customisation according to the preferred learning style of such students—a point for further research.

The positive impact of including GBL in a highly technical subject, such as finance, is evident from the Bayesian analyses. The results show a high probability of the educational game achieving a positive or satisfactory rating. Potentially, the results reflect the need for educators, especially in technical disciplines, such as finance, to become innovative regarding the use of technology and move away from a focus on only traditional resources for satisfactory student learning in the contemporary era. Further, two aspects of the game—functionalities and usability and perception of impact—are particularly noted to influence the game's overall rating. In a recent work, Mosiane and Brown [63] note that the extent to which online games are effective for learning depends on the games' fit with the learning tasks and players' perceptions of their usefulness. The research further notes that the frequency of playing a game and its intensity do not necessarily shape its effectiveness,

and players can achieve the learning task even from infrequent playing [63]. Arguably, our findings that more than a game's content, the game's usability and perception of the game's impact influence the overall game experience, especially for an educational game in a highly technical business subject, corroborate this view. Especially when planning an educational game to teach a technical business discipline, such as finance, and within an online setting, there potentially needs to be a careful consideration of the learners' requirements, level of understanding and capability towards ensuring an enjoyable outcome rather than only focusing on a game's content or context.

## 7. Conclusions

This article explores the potential of computer-based GBL for teaching undergraduate finance—a discipline, which is highly technical and challenging among business subjects, and for which there has been limited exploration of GBL's effectiveness. We obtained interesting outcomes by trialling a quiz-like computer game at an Australian university and assessing respective players' responses to a survey. First, the results imply that such GBL is more likely to acquire a positive rating than otherwise. We also note that as long as users feel that they are learning and benefiting from educational games and can connect the relevance of that learning to their professional or personal development contexts, they are likely to be satisfied despite weaknesses in aesthetics or functionalities. We further find that more than a game's content, the game's usability and players' perception of the game's impact may influence the overall game experience, especially for an educational game in a highly technical business subject, especially within online and high student diversity contexts.

There are some limitations of this research. A notable limitation is the minimal responses to the survey achieved so far and the consequent difficulty in making a generalised conclusion. However, a defining aspect of this research is the use of Bayesian analysis. Bayesian analysis allows insights even for small sample sizes but has not been widely used in the higher education research area in favour of the frequentist analysis. The use of Bayesian analysis in the article, hence, may further encourage other research work in this space. Additionally, the game was rolled out as a learning resource only for a specific undergraduate finance subject at a particular institution, and it will be interesting to note the impact of gamification in other subjects. However, research in the relevant area often considers similar institution and subject-specific interventions, and as such, the narrowed scope of intervention for this project makes sense.

Future research will undertake controlled experiments to assess the impact further. It will also be interesting to promote the game for teaching finance concepts in other institutions—another possibility for future work. Another future extension planned is using other types of games instead of quiz games.

Overall, GBL has a high potential for teaching highly technical business subjects, such as finance, especially in an online learning context. This calls for further investigations in the field.

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**Institutional Review Board Statement:** The study was conducted in accordance with the protocol for conducting human research in Australia and approved by the Ethics Committee of CQUniversity (Project Number: H16/06-170 and date of approval: 6 July 2016).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data used in the study is available on request and subject to relevant institutional approval from the 1st author and is not publicly available due to privacy and ethical restrictions.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A. The Survey Questionnaire

1. What is your current study status? (select all that apply)

- ☐ Full-time student
- ☐ Part-time student
- ☐ Distance education
- ☐ On-campus student

2. What is/are your major area(s) of study? (select all that apply)

- ☐ General Business Management
- ☐ Accounting
- ☐ Financial Planning
- ☐ Property
- ☐ Law

Other (please specify)

3. What is your current professional status? (select all that apply)

- ☐ Unemployed or not working
- ☐ Working for an organisation full time
- ☐ Working for an organisation part time
- ☐ Running a business

Other (please specify)

4. In which age range will you place yourself?

- ○ 18–24
- ○ 25–34
- ○ 35–44
- ○ 45–54
- ○ 55–64
- ○ 65+

5. How do you feel about your information technology (IT) competence?

- ○ Not much or am somewhat new to using IT
- ○ Have good knowledge of general software and IT tasks like emailing, browsing, document setting
- ○ Have advanced knowledge of IT and software like spreadsheet use, database applications

6. How well are you familiar with financial markets?

- ○ Unfamiliar or have little knowledge
- ○ Have some knowledge about financial markets like share and bond markets in general
- ○ Have expert level of knowledge about financial markets like trading and risks

7. On a scale of 1 to 5, where 1 means highly unsatisfactory and 5 means highly satisfactory, how will you overall rate the game you played?

| | | | | |
|---|---|---|---|---|
| ○ 1-Highly Unsatisfactory | ○ 2 | ○ 3 | ○ 4 | ○ 5-Highly Satisfactory |

8. On a scale of 1 to 5, where 1 means strongly disagree and 5 means strongly agree, how will you rate the game concerning its features?

| | | | | | |
|---|---|---|---|---|---|
| I found the game engaging | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| I found the game enjoyable | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| The game is easy to use | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| The game has good visual outlook | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| I feel the game is well planned | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| I did not face any technical issue when using the game | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| Encountered situations in the game motivated me to think thoroughly on learning resources | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| Encountered situations in the game assisted me to learn covered topics better than textual resources | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| Encountering situations in the game assisted me in solving assessment problems easily | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| I feel the situations encountered represent real-world scenarios | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| I believe solving tasks in the game will assist me professionally | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| I had a memorable experience from playing the game | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| Overall, I feel the game is supportive of learning | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |
| Overall, I feel playing the game has helped me with assessment tasks | 1-Strongly Disagree | 2 | 3 | 4 | 5-Strongly Agree |

9. Do you have any comments regarding your rating of the game and its features?
10. Is this the second or more time you are completing this survey? If Yes, please comment on this new rating.

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