International Journal of Serious Games

ISSN: 2384-8766
https://journal.seriousgamessociety.org/

Article

Predictors of Flow Experience and Knowledge Acquisition in a STEM Game

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Keywords:
Educational game
Technology acceptance
Knowledge Acquisition
Flow Experience
Prior Knowledge
Self-Efficacy

Received: April 2023
Accepted: July 2023
Published: August 2023
DOI: 10.17083/ijsg.v10i3.619

Abstract

Prior work systematically investigating the factors contributing to flow experience and learning in educational games is scarce. The relationship between learners' acceptance of the game and individual difference variables relevant to game-based learning and learners' flow experience and learning still needs to be systematically explored. To address the gap in knowledge, the study aimed to systematically examine whether variables of technology acceptance and individual differences relevant to game-based learning may predict flow experience and knowledge acquisition in an educational game. A total of 69 undergraduate students participated in the current study. Results indicated students' flow experience was predicted by some constructs of technology acceptance, namely, perceived playfulness and perceived attractiveness of the game. Five constructs of technology acceptance of the game, however, did not significantly predict learners' knowledge acquisition, although the correlation between perceived playfulness and knowledge acquisition from the game approached significance. Prior knowledge was found to be a negative predictor of knowledge acquisition from the game, that is, those with insufficient prior knowledge achieved greater knowledge acquisition from the game. Findings were discussed, and suggestions for future research were provided.

1. Introduction

1.1 Educational Games

Development in technology has resulted in advancement in learning and teaching methods, and one area that has been growing is educational games [1], [2]. One of the goals of educational games is to create engaging learning experiences for achieving learning goals, outcomes, and experiences [3]. By scrutinizing empirical studies conducted between 2000-2018, a recent meta-analysis [1] examined the effects of educational games on learners' academic achievement. Their findings suggested the positive effects of educational games on students' academic achievement. Their findings based on the subgroup analysis further revealed that the impact of educational games on academic achievement did not differ by the sub-levels of schooling, the different types of reporting, or various disciplines.

Educational games have been used to address many subjects, among which mathematics, science, and language are the most popular subject areas to be supplemented by educational games[4]. In particular, educational games have shown significant potential for improving learning STEM topics, and the use of games in STEM learning has been undergoing remarkable growth [5]. More specifically, educational games have been widely used to facilitate STEM learning, including algebra [6], physics [7]–[9], biology [10], among other STEM subjects. Empirical evidence has suggested that educational games could provide a fun, engaging, and successful STEM learning experience [11]. Educational games represent a promising technology for increasing students' interest in and learning STEM topics [11].

Educational games have been shown to support learning by providing an engaging experience [12]. To be most effective, a STEM educational game needs to not only be able to support understanding of the content, but also constitute a highly engaging learning experience. One of the challenges of integrating educational games in the classroom is helping learners acquire knowledge from the game while maintaining a high level of learner engagement. A critical factor in learner engagement in game-based learning is flow. Flow is a construct underpinning educational games as a way to promote engagement in game-based learning. Therefore, it is critical to investigate factors contributing to the flow experience in game-based learning. To design an engaging experience for learners in educational games, it is important to understand why some learners end up with a low level of flow experience in the game or find it difficult to immerse themselves in the game.

The need to identify the predictors of flow experience and learning is critical as a positive learning and flow experience will encourage learners to continue using educational games and benefit from the games. The current study will generate practical implications for game designers to prioritize the relevant game aspects in the design in order to facilitate flow experience and learning in educational games. Furthermore, the findings will also be useful for instructors and educators as they provide instructional support that tailors to learners' needs as they adopt educational games.

Despite the fact that a multitude of educational games have been proposed and developed to support learning for the last two decades, prior work systematically investigating the factors that contribute to flow experience and learning in educational games is scarce [33]–[35]. The current study addresses this gap in knowledge, systematically investigating predictors of flow experience and learning in an educational game focusing on STEM learning. More specifically, the current study aimed to explore if the flow experience and knowledge acquisition from the game is affected by individual difference factors such as learners' prior knowledge, self-efficacy, and prior game playing experience as well as constructs of technology acceptance.

1.2 Flow Experience in Game-Based Learning

Educational games need to be well designed to support learner engagement [13]. The flow theory provides a foundation for designing learner engagement. Flow is defined as an optimal mental state when the learner is engaged in the task, and is fully immersed with considerable concentration and enjoyment [14]. Flow experience refers to a situation of complete engagement in a task [14]. Flow was operationalized as an experience that is "(1) characterized by a seamless sequence of responses facilitated by machine interactivity, (2) intrinsically enjoyable, (3) accompanied by a loss of self-consciousness, and (4) self-reinforcing" (p. 57) [15]. In the context of game-based learning, [16] found that flow experience was related to positive feelings during gameplay. Furthermore, [17] found that flow experience influenced learners' behavior patterns associated with in-depth reflective processes.

1.3 Technology Acceptance Model

A high level of technology acceptance by the learners is the prerequisite for the successful adoption and continuous use of educational games for learning purposes. Theoretically, the technology acceptance model (TAM) is a prominent theoretical model that predicts and explains learners' acceptance of new technology [18]. The TAM model provided insights into factors influencing acceptance of new technology.

The existing literature has witnessed a wide application of the Technology Acceptance Model (TAM) to predict and explain learners' acceptance of educational technologies, which include but are not limited to virtual reality [19], augmented reality [20], open educational resources [21], online video [22], mobile learning technologies [23], [24], collaborative technologies [25], and tablet computers [26].

In the original technology acceptance model proposed by [18], it was suggested that the two main constructs influencing the acceptance of new technology are perceived usefulness and perceived ease of use [18]. Perceived usefulness is defined as one's belief that using a technological tool will enhance performance [18]. Perceived ease of use is defined as a person's belief that using a particular technology would be free from effort [18].

Although the initial technology acceptance model (TAM) focused on the utilitarian aspects (i.e., perceived usefulness and perceived ease of use) of individuals' acceptance of new technologies, the model has been expanded to include more variables to predict the acceptance of a technological tool. These other variables included perceived playfulness [27], perceived attractiveness [28], and attitude toward use [29]. More specifically, [27] integrated the construct of perceived playfulness into the technology acceptance model. Perceived playfulness is a construct that includes one's enjoyment, psychological stimulation, and interests. The construct of perceived playfulness is particularly relevant as it relates closely to the flow experience. More specifically, researchers have proposed a closely relevant construct - enjoyment, as a major characteristic of one's flow experience in similar contexts to game-based learning [30]–[32]. Later, [28] introduced the construct of perceived attractiveness to the TAM model. Their study was conducted in the context of using a website and perceived attractiveness was defined as ''the degree to which a person believes that the website is aesthetically pleasing to the eye'' (p. 544). Then, the construct of attitude toward use was added to the TAM model, which refers to a person's positive or negative feelings toward a technological tool [29].

1.4 Technology Acceptance, Flow Experience, and Game-based Learning

The literature search revealed only a limited number of empirical studies have examined the influence of constructs of technology acceptance on learning and flow experience in game-based learning [33]–[35]. For example, [33] designed and developed a serious game on product design. The researchers examined the relationship between the mechanics and dynamics of the game; perceived usefulness, perceived ease of use, goal clarity; and ultimately concentration and user enjoyment, among a group of undergraduate students. The findings showed these two constructs of technology acceptance (i.e., perceived usefulness and perceived ease of use) explained 60% of the variance in learners' enjoyment. In a more recent study, [34] investigated the influence of students' acceptance of game-based learning as well as their intrinsic motivation for math and flow experience on learning in a math game. Additionally, the researchers investigated the influence of perceived usefulness and perceived ease of use of the game as well as learners' intrinsic motivation for math on flow experience. The results indicated that students' learning and flow experience were predicted by students' perceived usefulness and perceived ease of use of the game and their intrinsic motivation for math. Similar findings were obtained by [35], which noted that learners' flow experience was significantly correlated with learners' perceived usefulness and perceived ease of use of the game.

Previous research has suggested the links among several constructs of technology acceptance, flow experience, and learning as applied to various research contexts [31], [36], [37]. The previous studies examined learners' game acceptance focusing on two constructs of technology acceptance (i.e., perceived ease of use and perceived usefulness, [33]–[35]). A literature search revealed no research had examined other dimensions of technology acceptance (e.g., perceived attractiveness, perceived playfulness, and attitude toward use). Therefore, the current study was designed to systematically examine the effects of the five constructs of technology acceptance on flow experience and knowledge acquisition from the game.

1.5 Self-Efficacy and Game-Based Learning

Self-efficacy is defined as one's belief in the capability to execute a task successfully [38]. [39] also suggested the specificity of the task when discussing self-efficacy, suggesting self-efficacy is related to a specific task or context. For example, a learner may have a high level of self-efficacy in solving a math problem but may have a low level of expectancy for success in cooking.

An individual determines the level of self-efficacy by drawing on information from four sources of information, and these are mastery experiences, social persuasion experiences, vicarious learning experiences, and physiological states [38]. Of the four sources of information, mastery experiences constitute the most influential one that affects learners' formation of self-efficacy beliefs [38]. More specifically, a successful completion of a task would allow the learners to interpret the experience as successful and use the interpretations to develop a positive set of beliefs about their future success with a similar task. In contrast, an unsuccessful experience with the task would negatively affect learners' confidence in their ability to successfully complete a similar task in the future. In the context of physics learning, research has demonstrated an association between learners' self-efficacy of physics learning and their understanding of physics concepts [40], [41].

Self-efficacy is an important construct in game-based learning as it would positively influence the amount of effort students would exert while playing educational games [42]. Theoretically, higher self-efficacy individuals would more likely engage themselves in the learning process and experience high levels of engagement and concentration, resulting in a flow experience compared to their counterparts with lower self-efficacy [43]. Empirical evidence has suggested self-efficacy could influence learners' flow state and knowledge acquisition from educational games [44]–[46].

1.6 Prior Knowledge and Game-Based Learning

Research has also suggested that prior knowledge affects flow experience and knowledge acquisition from an educational game, as it affects learners' ability to process new information [35]. Prior knowledge is represented by the number of schemata stored in the long-term memory. Learners who process more prior knowledge tend to possess more relevant information in their long-term memory, which can be integrated with the new information acquired from the game. They would less likely experience idle time during game playing [35]. Learners with insufficient prior knowledge may find the learning activities in the game too challenging. As flow reflects the degree of learners' immersion in the game and the balance between game challenges and learners' current skill level [14], [47], it is possible those learners with a low level of prior knowledge may experience a lower level of flow compared to their peers who have a sufficient amount of prior knowledge.

Previous work has suggested the role of prior knowledge in flow experience in educational games [35], [48], [49]. For example, [35] examined the relationship between participants' prior knowledge of the subject matter (i.e., computer assembly), their learning from the game, as well as their flow experience in a problem-solving-based educational game. The results from the study suggested that students with higher prior knowledge achieved higher flow experience, compared to individuals with limited prior knowledge. The authors suggested that these high prior knowledge learners found the gameplaying experience enjoyable simply from the process of playing the game instead of expecting to obtain other benefits in the future. With respect to the role of prior knowledge in learning from the game, the study indicated those with a sufficient level of prior knowledge did not achieve a significant learning gain from the game. In contrast, students with limited prior knowledge of the subject achieved desirable learning outcomes from the game, as long as they experienced an adequate flow experience from the game. Based on these findings, it is reasonable to speculate that prior knowledge may have an impact on the flow experience and knowledge acquisition from the game.

1.7 The Current Study

It was not clear from previous research whether students' improved perceptions about the educational game (i.e., constructs of technology acceptance) would lead to enhanced knowledge acquisition from the game and flow experience, and the empirical evidence has been limited [50]. Furthermore, STEM subjects such as physics are perceived as not interesting by most learners, and thus it is important to provide an enjoyable experience while also promoting learning from the game [51]. Thus, the current study aimed to systematically examine factors that contribute to a flow experience and knowledge acquisition from the game. More specifically, the study was designed to answer whether and how students' perceptions of the game focusing on the constructs of technology acceptance (i.e., perceived ease of use, perceived usefulness, perceived playfulness, perceived attractiveness, attitude toward use) and individual differences relevant to game-based learning (i.e., prior knowledge, self-efficacy, prior game playing experience) may predict flow experience and learning in an educational game on Newtonian mechanics. The following two research questions were examined in this study.

RQ1: To what extent do students' acceptance of the game (i.e., perceived ease of use, perceived usefulness, perceived playfulness, perceived attractiveness, and attitude toward use) as well as several individual differences relevant to game-based learning (i.e., prior knowledge, self-efficacy, prior game playing experience) predict flow experience in a physics game?

RQ2: To what extent do students' acceptance of the game (i.e., perceived ease of use, perceived usefulness, perceived playfulness, perceived attractiveness, and attitude toward use) and individual differences relevant to game-based learning (i.e., prior knowledge, self-efficacy, game playing experience) predict learning in a physics game?

2. Methods and Material

2.1 Participants

IRB was approved by the university's Institutional Review Board prior to data collection. A total of 69 college students representing diverse majors participated in the study. Of these participants, 26.09% were male, 71.01% were female, and 2.90% were non-binary. The average age of the respondents was 21.42 years old. No participants had any exposure to the game adopted in the current study. Table 1 presents the descriptive characteristics of the participants, including gender, age, undergraduate classification, and prior game playing experience.

Table 1. Descriptive Characteristics of Participants.

Variables	Statistics
Gender	18 Male 49 Female 2 Non-binary
Age	M = 21.42 (SD = 3.23)
Undergraduate Classification	26 Junior 15 Sophomore 24 Senior 4 N/A
Prior Game Playing Experience	43: Not at all 17: 1-3 hours 6: 4-6 hours 2: 7-9 hours 1: More than 9 hours

2.2 Game-Based Learning Environment

In the current study, the participants played an educational game called SURGE [7], which focused on a topic in physics - Newtonian mechanics. The SURGE game "engages students in learning about Newtonian mechanics through exploration, prediction, and observation rather than through rote learning" [7]. More specifically, learners were instructed to operate the spaceship and rescue the fuzzies, while minimizing collisions with the walls. In order to successfully navigate the mazes through various challenges embedded within the game that are related to Newtonian mechanics, learners were instructed to apply correct forces, constant acceleration, or impulses to the spaceship, thus adjusting the velocity of the spaceship or maintaining a constant velocity. As the challenges in the game are linked to Newtonian mechanics concepts, learners would be able to apply principles of Newtonian mechanics and develop an understanding of the concepts. Regarding the effectiveness of this specific educational game on participants' learning, the game has been empirically proven to have a positive influence on students' learning of Newtonian mechanics [7].

2.3 Procedures

Data was collected from one individual at a time in the lab. First, after signing the informed consent, participants completed a survey implemented on Qualtrics, which included questions on gender, age, ethnicity, undergraduate major, prior game playing experience, as well as self-efficacy of learning physics. Participants then responded to the test measuring their prior knowledge. Then, participants played the first two levels (i.e., constant force and impulse) within a 30-min limit, while their visual behavior being registered (the data is not reported in this paper). After the game playing session, participants responded to the post-test on learning which included the same set of questions in the pre-test. A 10-min limit was imposed for both the pre-test and the post-test. Then the participants answered the questions on flow experience and several constructs of technology acceptance, including perceived ease of use, perceived usefulness, perceived playfulness, perceived attractiveness, and attitude toward use.

2.4 Measures

2.4.1 Self-Efficacy

Eight statements adapted from an existing scale were adopted to measure learners' self-efficacy levels in learning physics [52]. This measure has been previously validated and has been used in previous studies to measure participants' level of self-efficacy in multiple subjects [52]–[55]. Participants indicated how much they agreed with statements from strongly disagree (1) to strongly agree (5). Example statements included "I have a lot of self-confidence when it comes to physics"; "I am not the type to do well in physics" (reversed). Strongly disagree with the statement "I am not the type to do well in physics" will receive the score of "-1" and strongly agree with this statement will receive the score of "-5". Scores for each statement were summed to represent participants' levels of self-efficacy (M = 14.6, SD = 5.94). Cronbach's alpha for the measure of self-efficacy is 0.883.

2.4.2 Pre-Test and Post-Test on Learning

Participants' knowledge of Newtonian mechanics prior to and after the game play was measured by a validated scale - Force Concept Inventory (FCI, [56]). A total of 9 multiple-choice questions were included on the learning test, containing 3 questions on impulse, 2 questions on interpreting kinematics, and 4 questions on constant acceleration. Cronbach's alphas for the pre-test and the post-test on learning were 0.651 and 0.711, respectively.

2.4.3 Flow Experience

After playing the game, participants were instructed to rate their level of agreement with four statements (α = .735, [47]) on a 5-point Likert scale from 1: strongly disagree to 5: strongly agree. The data from the current study suggested the educational game on Newtonian mechanics overall fostered flow experience among the participants (Table 2).

Table 2. Descriptive Statistics for Flow Experience Scores.

Statements *During playing the game, I felt:*	**Mean**	**SD**
1. I really enjoyed the playing experience.	4.25	0.91
2. My attention was focused entirely on playing the game.	4.65	0.72
3. During playing, I was not concerned with what others may have been thinking of my playing performance.	4.03	1.24
4. I was totally immersed in playing the game.	4.29	0.84
Average Score	**4.30**	**0.57**

2.4.4 Technology Acceptance

Several questions were included in the post-game survey to gauge participants' acceptance of the game based on the Technology Acceptance Model (TAM, [18]). The scales included questions adapted from the validated scales on five dimensions (see Table 3), namely, perceived ease of use [18], perceived usefulness [18], perceived playfulness [27], perceived attractiveness [28], and attitude toward use [29]. These measure have been widely used in previous studies to measure the different constructs of technology acceptance [21], [22], [24], [57], [58]. The scales were adapted from existing measures for the current study. All items were anchored on a 5-point Likert scale. Participants rated their agreement with statements on a Likert scale ranging from 1: strongly disagree to 5: strongly agree. Results indicated the participants had a high level of technology acceptance of the game. All constructs of technology acceptance have obtained adequate reliability based on the Cronbach's alpha values (see Table 3).

Table 3. Descriptive Statistics for Participants' Acceptance of the Game.

Constructs	**Mean**	**SD**
Perceived ease of use (alpha = .688)		
The SURGE game provides clear guidance.	4.42	0.93
The SURGE game is easy to use.	4.61	0.60
The operation of the SURGE game does not require too much time.	4.48	0.93
Average Score	**4.50**	**0.66**
Perceived usefulness (alpha = .674)		

The SURGE game is useful in leading to better understanding of Newtonian Mechanics.	4.13	0.73
The SURGE game is useful in increasing my learning efficiency in Newtonian Mechanics.	4.07	0.73
The SURGE game is useful in enhancing my desire to learn Newtonian Mechanics.	3.41	1.15
Average Score	**3.87**	**0.74**
Perceived playfulness (alpha = .785)		
Time flies when I use the SURGE game.	3.97	0.98
It is interesting to use the SURGE game.	4.39	0.83
I feel like exploring more information when I use the SURGE game.	3.51	1.21
Average Score	**3.96**	**0.85**
Perceived attractiveness (alpha = .894)		
I am attracted by the general appearance of the SURGE game.	3.61	1.15
I am attracted by the combination of colors used in the SURGE game.	3.86	1.03
I am attracted to the SURGE game as a whole.	3.86	1.06
Average Score	**3.77**	**0.98**
Attitude toward use (alpha = .837)		
I like using the SURGE game to learn Newtonian Mechanics.	4.20	0.95
I have a positive attitude toward using the SURGE game.	4.45	0.80
I feel that using the SURGE game to learn Newtonian Mechanics is a good method.	4.10	0.89
Average Score	**4.25**	**0.77**

3. Results

3.1 Data Pre-Processing for Analysis

Data were cleaned and organized prior to analysis. Points were assigned based on their selection of hours on the scale of prior game playing experience. Participants' self-efficacy scores were calculated by summing the values for each statement measuring the self-efficacy level. Participants' prior knowledge was represented by their scores on the pre-game test on learning.

For the measure of technology acceptance, the total score for each subscale was utilized to represent various constructs of technology acceptance (i.e., perceived ease of use, perceived usefulness, perceived playfulness, perceived attractiveness, and attitude toward use).

Learners' knowledge acquisition was calculated based on the difference in scores from the pre-test to the post-test. For the measure of flow experience, average scores were used to represent participants' flow experience.

3.2 Technology Acceptance, Individual Differences, Flow Experience

With respect to the correlations between flow experience and variables of individual differences (i.e., self-efficacy, prior knowledge, and prior game playing experience) as well as several constructs of technology acceptance, the correlation analysis revealed that the flow experience score was significantly correlated with several constructs of technology acceptance, namely, perceived usefulness, $r(68) = .332$, $p < .01$, perceived playfulness, $r(68) = .542$, $p < .01$, perceived attractiveness, $r(68) = .499$, $p < .01$, and attitude toward use, $r(68) = .352$, $p < .01$. Several variables within the technology acceptance model are intercorrelated. Table 4 overviews the bivariate correlations among all the variables included in the current study.

Table 4. Summary of One-Tailed Bivariate Correlations among Predictor and Outcome Variables.

Variable	1	2	3	4	5	6	7	8	9
1. Self-efficacy	-								
2. Prior knowledge	.331**	-							
3. Prior Game playing experience	.156	.102	-						
4. Perceived ease of use	.142	.183	.227*	-					
5. Perceived usefulness	.237*	-.009	.034	.291**	-				
6. Perceived playfulness	.183	-.035	.103	.207*	.631**	-			
7. Perceived attractiveness	.145	.049	.185	.308**	.540**	.691**	-		
8. Attitude toward use	.079	-.009	.242*	.394**	.599**	.748**	.748**	-	
9. Flow experience	.188	.013	.062	.164	.332**	.542**	.499**	.352**	-

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

Before running the regression model, assumptions including independence, homogeneity of variance, linearity, and noncollinearity were tested. The analysis indicated one outlier exerted influence on the model based on Cook's Distance and Centered Leverage Value, and so was removed from the dataset. The final dataset ($n = 68$) met the assumption of normal distribution based on skewness and kurtosis values and was included in the multiple regression model.

The multiple regression model was run to answer the research question with the flow experience score serving as the outcome variable. Eight predictor variables were included in the regression model, and they were entered simultaneously: 1) self-efficacy; 2) prior knowledge; 3) prior game playing experience; 4) perceived ease of use; 5) perceived usefulness; 6) perceived playfulness; 7) perceived attractiveness; 8) attitude toward use. The regression model with the flow experience score as the outcome variable was significant at $F(8, 59) = 4.285$, $p < .001$, R2 = .367. Table 5 summarizes the results. The findings indicated that perceived playfulness positively predicted participants' flow experience score, $\beta = .532$, $t = 3.000$, $p < .01$. For each unit increase in the perceived playfulness score, the flow experience score increased by .532 units. Further, perceived attractiveness was found to positively predict participants' flow experience score, $\beta = .372$, $t = 2.256$, $p < .05$. For each unit increase in the perceived attractiveness score, the flow experience score increased by .372 units. Other variables were not found to be significant predictors of participants' flow experience scores.

Table 5. Predictors of Flow Experience.

Variable	*β*	*t*	*p*
1. Self-efficacy	.072	.620	.538
2. Prior knowledge	-.028	-.250	.803
3. Game playing experience	-.006	-.051	.959
4. Perceived ease of use	.080	.679	.500
5. Perceived usefulness	-.046	-.317	.752
6. Perceived playfulness	.532	3.000	**.004**
7. Perceived attractiveness	.372	2.256	**.028**
8. Attitude toward use	-.333	-1.705	.093

3.3 Technology Acceptance, Individual Differences, Knowledge Acquisition

With regard to the relationship between knowledge acquisition and individual differences in prior knowledge, self-efficacy, and prior game playing experience as well as multiple constructs of technology acceptance, the correlation analysis revealed the correlation between knowledge acquisition and perceived playfulness approached significance (r = .202, p = .05). Prior knowledge was found to be positively correlated with self-efficacy. Table 6 summarizes the bivariate correlations among the variables.

Table 6. Summary of One-Tailed Bivariate Correlations among Predictor and Outcome Variables.

Variable	1	2	3	4	5	6	7	8	9
1. Self-efficacy	-								
2. Prior knowledge	.331**	-							
3. Game playing experience	.156	.102	-						
4. Perceived ease of use	.142	.183	.227*	-					
5. Perceived usefulness	.237*	-.009	.034	.291**	-				
6. Perceived playfulness	.183	-.035	.103	.207*	.631**	-			
7. Perceived attractiveness	.145	.049	.185	.308**	.540**	.691**	-		
8. Attitude toward use	.079	-.009	.242*	.394**	.599**	.748**	.748**	-	
9. Knowledge acquisition	.009	-.286	-.130	.071	.124	.202	.113	.255	-

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

No violation of the assumptions for multiple regression was found. The multiple regression model was run on the dataset (n = 68) to answer the research question with knowledge acquisition serving as the outcome variable. The same set of eight predictor variables used for the flow experience's multiple regression model were included in the model, and they were entered into the regression model simultaneously. The regression model with knowledge acquisition as the outcome variable was not significant at F(8, 59) = 1.915, p = .075, R2 = .206. Results suggested prior knowledge as a negative predictor of knowledge acquisition from the game, that is, those with a lower level of prior knowledge achieved greater knowledge acquisition from the game, β = -.313, t = -2.481, p < .05. Other variables did not significantly predict knowledge acquisition from the game. Table 7 summarizes the results.

Table 7. Predictors of Knowledge Acquisition.

Variable	*β*	*t*	*p*
1. Self-efficacy	.147	1.125	.265
2. Prior knowledge	-.313	-2.481	**.016**
3. Game playing experience	-.210	-1.682	.098
4. Perceived ease of use	.061	.459	.648
5. Perceived usefulness	-.119	-.739	.463
6. Perceived playfulness	.033	.165	.870
7. Perceived attractiveness	-.151	-.815	.418
8. Attitude toward use	.426	1.948	.056

Note. R^2 = .206, $F(8, 59)$ = 1.915, p = .075.

4. Discussion

4.1 Discussion of Main Results

The study examined the influences of individual differences (i.e., prior knowledge and self-efficacy) and multiple constructs of technology acceptance (i.e., perceived ease of use, perceived usefulness, perceived playfulness, perceived attractiveness, attitude toward use) on participants' flow experience and knowledge acquisition from a physics game. The findings of the current study suggested two constructs of technology acceptance, namely, perceived playfulness and perceived attractiveness of the game significantly predicted learners' flow experience in the educational game. Constructs of technology acceptance of the game, however, did not significantly predict knowledge acquisition, although the correlation between perceived playfulness and knowledge acquisition approached significance. Participants' knowledge acquisition from the game was negatively predicted by their prior knowledge of the subject (i.e., Newtonian mechanics). Specifically, the findings suggested the learners who had a low level of prior knowledge achieved greater knowledge acquisition from the game (i.e., increase from pre-test to post-test). The current study made contributions to the literature in that the current study systematically investigated what factors predicted the flow experience and knowledge acquisition from a game from two perspectives (i.e., the perspectives of technology acceptance and the individual differences perspective).

The findings indicated, in general, learners achieved a positive flow experience within the game. The physics game focusing on Newtonian mechanics was engaging and led to a positive experience full of enjoyment. The findings suggested that perceived attractiveness and perceived playfulness are both positive contributors to the flow experience associated with the game. The current findings on the flow experience in the current study suggested that educational game designers should consider designing game features and mechanisms in a way to enhance the perceived playfulness and perceived attractiveness of the game, so that learners could achieve a high level of flow experience while playing the game. More specifically, designers of educational games are recommended to design game to present optimal challenges to the learners and provide support for them to overcome the challenges. The current study also called for the need for close collaboration among game designers and practitioners, to ensure the game will be perceived as attractive and playful by the learners.

The current study also indicated that participants' learning from the physics game was negatively associated with their pre-existing knowledge of the subject matter. It is possible that learners with high prior knowledge already knew the material to some extent and therefore, engaged in the game introducing what they already know. The findings of the current study were in alignment with previous research suggesting the role of prior knowledge in knowledge acquisition from an educational game [35]. The study has generated important implications for practice for game designers and practitioners who adopt games for instructional purposes. The findings suggested the game should be designed to accommodate learners' pre-existing level of knowledge of the subject matter. The findings may generate implications for the design and development of future educational games that aim to accommodate a wide range of learners with individual differences in their levels of prior knowledge. Designers and developers of educational games should consider learners' pre-existing differences such as prior knowledge and aim to provide differentiated instructions for learners with varied levels of prior knowledge, possibly different game levels and adaptive guidance within each level. Game designers should also consider emphasizing challenges within the game and promote engagement and learning, while considering players' pre-existing individual differences, such as prior knowledge, which was found to influence knowledge acquisition from the game. Game designers are recommended to design activities within the game that are in the players' Zone of Proximal Development (ZPD) [59], keeping them maximally engaged. Furthermore, in order to maximize learning for students with varied levels of prior knowledge of the subject matter, stealth assessment [60] could be incorporated into the game to assess leaners' competency levels, and adaptive trajectory in the game could be applied in games in order to accommodate learners' various levels of competency. Game designers and teachers are recommended to provide prompt real-time feedback guidance and provide customized learning support. For example, one recent study specifically examined the adaptive designs in game-based learning and noted that adaptive designs in educational games contribute to learning and engagement [61].

4.2 Limitations and Future Research

Several limitations of the study need to be pointed out and enlighten directions for future research.

First, the small variances explained in the regression model suggested that some other factors may also play a role in influencing learners' flow experience and knowledge acquisition from the educational game. For example, existing evidence has suggested that learning styles could impact students' knowledge acquisition in game-based learning environment [62]. It has also been shown that flow experience was correlated with learners' intrinsic motivation [63]. Moreover, the current study did not explicitly study how game design mechanics or features may influence students' flow experience and knowledge acquisition from the game. To be more specific, certain game features in an educational game [6], [64] are designed to enhance learning and create engagement. Empirical evidence has suggested these characteristics may affect learners' perceived ease of use and perceived usefulness of the game, which ultimately influences learner engagement [33]. For example, studies have found the occurrence of flow experiences depends on the games' interactive mechanisms [48], [65]. Factors that would influence the flow experience and knowledge acquisition from an educational game are still not completely understood, which warrants more research to further examine and identify other potential factors contributing to the flow experience and knowledge acquisition in an educational game.

Second, the current study required the participants to self-report the flow experience within the educational game. The findings of the current study were based on self-reported data and participants' subjective perceptions of their game playing experience. Despite being a common practice in educational research, the self-reported scores of flow experience failed to capture the granularities of the game playing process as it was administered upon completion of the educational game. Future research should incorporate data sources on a more fine-grained level. It is recommended future researchers could collect game log data and in-game assessments during the gameplay in order to study the underlying processes of gameplay. Future studies could also adopt research methods such as concurrent think-aloud or analyze the video recording of game interaction, in order to examine the processes as learners engage in the gameplay. These types of measures along with the self-report measure will also contribute to the robustness of measurement.

Finally, the current study was conducted with a sample of undergraduate students. Future studies are suggested to examine if the finding may hold across a wider variety of populations and whether different factors examined in the current study would be more or less important in other populations with different ages and other demographic variables. Additionally, this study was conducted in a physics game. It is possible that results may vary in another educational game supporting the learning of other subjects. Testing the relationship among the variables of interest within games focusing on other subject areas is worthy of further exploration. Conducting more research could help improve our understanding of what factors could contribute to flow experience and knowledge acquisition in educational games designed for various learner populations and learning contexts.

5. Conclusions

The current study contributes to an understanding of how factors of technology acceptance and individual difference variables may impact flow experience and knowledge acquisition in an educational game. Results indicated students' flow experience was predicted by some constructs of technology acceptance, namely, perceived playfulness and perceived attractiveness of the game. Prior knowledge was found to be a negative predictor of knowledge acquisition from the game; that is, those with insufficient prior knowledge achieved greater knowledge acquisition from the game.

Acknowledgments

This study was funded by an internal grant at xxx university.

Conflicts of interest

The author declares that there is no conflict of interest.

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