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Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning

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ABSTRACT

In this paper, we investigate the impact of flow (operationalized as heightened challenge and skill), engagement, and immersion on learning in game-based learning environments. The data was gathered through a survey from players ($N = 173$) of two learning games (*Quantum Spectre*: $N = 134$ and *Spumone*: $N = 40$). The results show that engagement in the game has a clear positive effect on learning, however, we did not find a significant effect between immersion in the game and learning. Challenge of the game had a positive effect on learning both directly and via the increased engagement. Being skilled in the game did not affect learning directly but by increasing engagement in the game. Both the challenge of the game and being skilled in the game had a positive effect on both being engaged and immersed in the game. The challenge in the game was an especially strong predictor of learning outcomes. For the design of educational games, the results suggest that the challenge of the game should be able to keep up with the learners growing abilities and learning in order to endorse continued learning in game-based learning environments.

1. Introduction

Pervasive student disengagement is both a national and an international problem, with 20–25% of students in 28 OECD (Organisation for Economic Co-operation and Development) countries classified as having low participation and/or a low sense of belonging (Drigas, Ioannidou, Kokkalia, & Lytras, 2014; Willms, 2003). A promising strategy for increasing engagement in a meaningful way has been thought to stem from video games (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Gee, 2007; Steinkuehler, Squire, & Barab, 2012) and gamification (Hamari, Koivisto, & Sarsa, 2014) as observed by educational scholars for several decades.

In an ideal educational game setting, students learn how to solve complex problems. The problems within a game typically start off easy and then progressively become more difficult as players' skills develop. Players are motivated to learn, in part, because learning is situated and occurs through a process of hypothesizing, probing, and reflecting upon the simulated world within the game. In addition, the goals are clear, and information becomes available to players at just the time that it is needed to reach each goal. Making sense of that information becomes a goal intrinsic to gameplay. As McGonigal (2011) observed:

> *"In a good computer or video game you're always playing on the very edge of your skill level, always on the brink of falling off. When you do fall off, you feel the urge to climb back on. That's because there is virtually nothing as engaging as this state of working at the very limits of your ability. (p. 24)"*

Computer games have been observed to scaffold learning in ways that keeps players at the edge of their seats fostering continued interest in the game for hours, weeks, and even years. Players hone their skills and build knowledge as long as they continue to play. In some rare cases game developers, such as Valve (see Valve 2007, 2011), have described their effective design framework of "layered learning" which attempts to optimize learning elements consistent with interrelated principles of challenge, skills, engagement and immersion. In this framework,

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engagement and learning are necessary to keep players progressing in the game, and visa-versa. Entertainment game developers, however, are less concerned with how the learning may transfer to the outside world.

This study contributes to the current body of literature on learning by investigating the above mentioned psychological factors of challenges, skills, engagement and immersion that have been commonly believed to be characteristic to a good game and learning experiences. In the study, we investigated the relationship among these variables, and the extent to which they predict learning, in physics-based video games. The study also allowed us to explore the extent to which engagement and immersion may mediate the effect of challenges and skills on learning, as predicted by a theory of flow experiences (Csikszentmihalyi, 1990). Drawing on flow theory, perceived challenge and skills (the main two elements of flow) are hypothesized to predict engagement and immersion, which in turn are believed to predict perceived learning. We utilized a psychometric survey (see e.g. Nunnally, 1978) asking participants about their subjective learning experience after playing two video games designed by two research teams in the U.S. We then employed structural equation modeling in order to investigate these direct and mediated effects among flow (skill and challenge), engagement, immersion, and learning outcomes. The following research questions were examined:

1. Do challenge and skills predict engagement and immersion in game-based learning?
2. Do engagement and immersion predict perceived learning in game-based learning?
3. How engagement and immersion mediate the effect of challenge and skills on perceived learning in game-based learning?

1.1. Flow, engagement, and immersion in game-based learning

Serious games, gamification and game-based learning are distinct from entertainment-oriented games in that, while they are often also enjoyable, they are designed for primary end purposes other than entertainment and leisure (Davidson, 2008; Hamari & Koivisto, 2015b). Educational games, the focus of this study, are developed for the primary purpose of educating or training. Serious and educational games often combine the concentration demanded by challenging activities and the enjoyment experienced when maximally utilizing one's skills, as in "serious play" or "playful work" (Csikszentmihalyi & Schneider, 2000).

The integration of work and play characterizes the psychological state that Csikszentmihalyi (1990) has called "flow." Flow refers to a state of mind characterized by focused concentration and elevated enjoyment during intrinsically interesting activities (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003).

Research on flow in general has found that utilizing high degrees of skills in challenging tasks results in deep concentration, absorption, or immersion. Flow has also been related to learning, talent-development, academic achievement, and creative accomplishment in a profession (Csikszentmihalyi, 1996; Csikszentmihalyi, Rathunde, & Whalen, 1993). In the game-based learning and gamification contexts specifically, studies predict that learning and gamified curricula will become more and more commonplace as a method to invoke engagement and flow in students (Crisp, 2014). Moreover, studies have found these technologies do indeed invoke flow experiences (Hamari & Koivisto, 2014; Procci, Singer, Levy, & Bowers, 2012) and have the potential to affect consequent learning outcomes (Barzilai & Blau, 2014; Brom et al., 2014a; Chang, Wu, Weng, & Sung, 2012; Hung, Sun, & Yu, 2015; Liu, Cheng, & Huang, 2011; Sabourin & Lester, 2014) although there are also studies that find no significant association (e.g. Brom, Bromová, Děchtěrenko, Buchtová, & Pergel, 2014b). Therefore, investigating the structure of this phenomenon is essential. Specifically, what are conditions theorized as essential to flow experienced by players of games, to what extent do such conditions lead to greater engagement and immersion, and to what extent are conditions for flow and the engagement or immersion that these conditions may engender relate to learning through the game.

The subjective experience of flow, according to Csikszentmihalyi's (1990) theory, is enhanced by certain experiential conditions or properties of the task. The most central condition for flow experiences to occur is that the individual uses a high level of skill to meet a significant challenge. The activity is therefore not too easy for one's skills, nor is it impossibly difficult. Reaching the goal is doable: one has a reasonable chance of success with sincere and concerted effort. Typically, the challenge and skill are high and in balance—individuals stretch their skills to their limits in pursuit of a challenging goal. The various combinations of high or low challenges and skills predict distinct psychological states: (a) apathy, resulting from low challenge and low skill; (b) relaxation, resulting from high skill but low challenge; (c) anxiety, resulting from high challenge but low skill; and (d) flow, resulting from high challenge combined with high skill. This model later evolved into one with eight flow channels including four intermediary or transitional states between these four quadrants (Strati, Shernoff, & Kackar, 2012).

1.2. Challenge and skills in game-based learning

According to both Csikszentmihalyi's (1990) and Bronfenbrenner's (1979) theory, more cognitively complex and challenging classwork engages students more deeply. Research corroborates this theoretical stance, demonstrating that students are significantly more engaged and concentrate much harder when challenged in classrooms. The challenge-skill dynamic has also been found to increases motivation while extending players' capacities (Fullagar, Knight, & Sovern, 2013). When invited to engage in complex problem solving instead of confronting topics only superficially, students see more connections, becoming more intrinsically interested, and thus also pay better attention. Newmann (1992) referred to curriculum that fosters higher order thinking skills and is perceived as relevant as "authentic," but found authentic curricula in schools to be rare. Although some students might perceive being challenged as arduous and unpleasant, most students state that they like challenging work, value cognitive complexity, and are willing to work hard to complete schoolwork that challenges them (Newmann, Wehlage, & Lamborn, 1992). Conversely, national studies have repeatedly found that lack of challenge is a common reason for disengagement (Shernoff, 2010; 2013; Yazzie-Mintz, 2007).

Research has also shown that students have higher motivation, via greater self-efficacy and self-worth, when they perceived themselves to be competent (Covington, 1985). Perceptions of skill and competence have long been considered one of the most important determinants of achievement expectations, motivation, and behavior (Nicholls, 1979; White, 1959). Because success is positively valued and failure is negatively valued, people are inherently motivated and engaged to produce the feeling of competency. Some have argued that the perception of their competence and how it relates to perceived chances of success is a fundamental motivator for learning (Thomas, 1980), contributing to continuing motivation and global self-worth. Conversely, many students may feel at least somewhat uncomfortable or insecure as a function of perceived incompetence, resulting in a reluctance to take risks or take on new challenges that might increase competencies.

Engagement resembling flow experiences reflect a state of complete absorption in a challenging activity with no psychic energy left for distractions. All attention is focused on relevant stimuli.

For example, composers have described a shift in consciousness when music is "flowing" from the depth of their souls, stirred by inspiration, like being part of a river (Custodero, 2005). The high level of focus is often accompanied with a feeling that the activity is going well, that one is being successful, and often with feelings of inner peace, joy, or wonder. Csikszentmihalyi (1990) observes that when one loses self-consciousness during flow, this may lead to self-transcendence, a sense of expanding the boundaries of the self towards merging with one's environment. This description seems consistent with gamer's accounts of immersion or "being there" in the game. Research also suggests that the higher the challenge, the greater the engagement or sense of immersion (Shernoff, 2010).

This challenge-skill dynamic introduces a growth principle that is also inherently related to learning. When learning a new skill, the challenge of even a basic task may exceed a student's beginning level of ability, and hence one may feel overwhelmed. To reach flow, the level of skill must increase to match the challenge. Sufficient practice may be needed until the skill is mastered. Once mastered, a higher level of challenge is needed for one's skill level to increase yet again. Thus, individuals may progress through increasingly difficult challenges at ever-higher levels of skill. Because most video games allow the player to adjust the level of challenge as skills are increasing, the continuing cycle of new challenges results in the gradual building of increased competencies targeted by the game (Fullagar et al., 2013); and because the flow experience is so enjoyable, players are intrinsically motivated to improve their skills in order to meet the raised challenge and re-enter flow.

Generally, literature in the game-based context reflects similar understanding of the phenomenon that the challenge in games may drive a players' sense of flow and engagement (e.g. Wang & Chen, 2010; Hwang, Wu, & Chen, 2012). Prior research on challenges in game-based environments has indeed showed that challenge and skill are salient factors leading to the overall flow experience (Hamari & Koivisto, 2014; Hung et al., 2015; Procci et al., 2012; Wang & Chen, 2010). Furthermore, Hung et al., 2015 found that challenge in the game-based learning increased flow and learning outcomes as well as satisfaction. However, Ronimus, Kujala, Tolvanen, & Lyytinen, 2014 found no significant relationship between challenge and children's engagement in a game-based reading platform. While the factors and conditions related to flow and immersion in learning activities are often implied, overall prior studies systematically investigating the relationships among challenge and skill, engagement, immersion and further learning in game-based learning are scarce. This study attempts to contribute to the literature in this area by investigating both the antecedents of engagement and immersion as well as their impact on learning in meaningful game-based challenges.

1.3. Engagement and immersion in game-based learning

In this study, engagement is conceptualized as the simultaneous occurrence of elevated concentration, interest, and enjoyment encapsulating the experience of flow. All three phenomena are inherently related to learning (Shernoff, 2013). Concentration or absorption, which is central to flow (Csikszentmihalyi, 1990), is related to meaningful learning (Montessori, 1967), including depth of cognitive processing and academic performance (Corno & Mandinach, 1983). Interest directs attention, reflects intrinsic motivation, stimulates the desire to continue engagement in an activity, and is related to school achievement (Schiefele, Krapp, & Winteler, 1992). Enjoyment is a positive feeling related to the demonstration of competencies, creative accomplishment, and school performance (Csikszentmihalyi et al., 1993). In this conceptualization, engagement in learning is highest when all three components are simultaneously stimulated.

Engagement has been a canonical concept in game-based learning research. However, there are surprisingly few studies that actually measure psychological engagement in the game-based learning context. Engagement has been separated into three types of engagement: behavioral, cognitive and emotional (see e.g. Fredricks, Blumenfeld, & Paris, 2004). Pellas (2014) found that these three dimensions of engagement were correlated in a game-based learning environment. Coller and Shernoff (2009) found that those student who did homework and labs for an undergraduate engineering course in a game-based format were clearly more engaged in the activity than those who completed homework normally. Akkerman, Admiraal, and Huizenga (2009) found that 'storifying' history using mobile games had a positive effect on the student engagement. Previous studies have also found that voiceovers in a game can also have a positive effect on engagement in game-based learning environment (Byun & Loh, 2014). However, engagement into an educational game has also been observed to be moderated by gaming experience (Deater-Deckard, El Mallah, Chang, Evans, & Norton, 2014) and the nature of the learning tasks (Eseryel, Law, Ifenthaler, Ge, & Miller, 2013).

Previous studies have also found a positive association between engagement and learning (e.g. Hsu, Tsai, & Wang,2012; Huizenga, Admiraal, Akkerman, & Ten Dam, 2009) and that engagement in game can redirect unwarranted focus on grades to learning (Tüzün, Yilmaz-Soylu, Karakuş, Inal, & Kizilkaya, 2009). For example, Sabourin and Lester (2014) found that a game-based learning environment was able to both support learning and promote engagement. Hou (2015) and Brom et al. (2014a), however, establish a positive relationship between flow and learning. Admiraal, Huizenga, Akkerman, & Dam, 2011 found that flow had a positive effect on student performance in the game but did not have an effect on learning outcomes; however, if the students were engaged in a group competition, the more the students learned. Other studies have found that while games lead to learning gains, engagement remained unaffected (van der Spek, van Oostendorp, & Meyer, 2013).

Similarly, gamification settings have been found to influence engagement. For example, in the domain of commerce, Bittner and Shipper (2014) found that the effect of gamification on behavioral engagement was mediated by flow and enjoyment. Similarly, Hamari (2013, 2015) found that gamification increased trading activity but it was deemed that the results greatly depend on how engaged and interested the users are toward the gamification features in a service. In learning context, Huizenga et al. (2009) have similarly concluded that in order for the game-based solution to have an effect on learning, students should first actually be engaged within the game.

The sense of immersion characterizing flow experiences is also related to learning and related emotions (e.g. Fassbender, Richards, Bilgin, Thompson, & Heiden, 2012). For example, recent experiments in neuroscience have demonstrated that when a reader is fully engrossed in a novel, the human brain is activated not only in areas responsible for attention; it also dramatically "lights up" in areas controlling affect and emotion (Thompson & Vedantam, 2012). Flow theory has been a primary theoretical base for exploring the implications of learning through immersion or "being enveloped" by a virtual learning environment because the emotional composition of these experiences resemble flow and precipitate a deeper engagement with learning. Research has explicitly related the sense of "presence," "being there," "immersion," or "flow" in different virtual reality interfaces with positive learning outcomes (e.g., Abrantes & Gouveia, 2012; Fassbender et al., 2012). In addition, there is evidence that fantasy through simulations and games promotes intrinsic motivation and can enhance learning compared to instruction without fantasy elements (Lepper & Hodell, 1989; Parker & Lepper, 1992), in part by focusing the learner's attention on relevant features of the learning environment (Lepper & Molone, 1987).

However, currently there is a dearth of studies that investigate the relationship between immersion and learning in game-based learning environments. The only study (as far as we know) that does so, by Cheng, She, and Annetta (2015), found that immersion has a positive impact on learning outcomes especially when the players gaming performance was high.

Overall, according to larger theoretical developments as well as the body of empirical literature there is reason to believe that flow (challenge and skills), engagement, and immersion have a positive impact on learning. Research suggests that increases in challenge and skills relate to higher degrees of engagement and immersion; and that challenges, skills, engagement, and immersion may also relate to increased learning directly in addition to the mediated effects.

Thus far, there has also been little research that has applied structural research models among variables surrounding engagement and immersion to investigate their interdependencies and pathways to predicting learning. Most studies either investigate the relationship between game features and learning directly without measuring mediating psychological factors, or else investigate the relationship between game features and psychological factors but do not extended the measurement to further learning outcomes. In the present study, we investigate mediations and direct effects in order to gauge the phenomenon more reliably.

Based on the larger theoretical developments as well as the body of empirical literature, we hypothesize that increased challenge, skill, engagement, and immersion in a game or gamified experience will have a beneficial effect on learning. The specific hypotheses stemming from the three research questions outlined in Section 1 are described below and represented in Fig. 1.

2. Material and method

2.1. Participants and procedures

The study was conducted in two different settings. In one setting, 134 high school students in 11 classrooms across the U.S. played *Quantum Spectre* as part of their physics unit on optics. They took the survey as part of a post-class assessment. In the second setting, undergraduate mechanical engineering students played a game called, *Spumone*, as part of their engineering dynamics course. Students played the game throughout a fifteen-week semester and then took the survey within days before taking their final exam to complete the course. A total of 40 students completed the survey on *Spumone* and gave us permission to use their data for research.

The Games. *Quantum Spectre* is a puzzle-style game where each level requires the player to direct one or more laser beams to targets using a combination of flat and curved mirrors, lenses, beam-splitters, and other scientifically accurate optical devices (Fig. 2). When the appropriate color laser beam(s) has reached all the targets, a level is complete. In *Spumone*, students pilot a two-dimensional vehicle through subterranean, simulated world (Fig. 3). To be successful, students must devise strategies based on principles learned in an engineering dynamics course, and express those strategies mathematically through an equation parser embedded in the game.

The psychometric survey sought to measure the level of participants' subjective experience of challenge, skills, engagement, immersion, and perceived learning based items. In the survey, respondents were given the prompt: "Think back over your entire experience with the game. Please answer the following questions." Two to three items were asked as indicators for each of the following constructs: concentration, enjoyment, interest, challenge, skills, immersion, and perceived learning. For example, items measuring the interest construct were "How interesting was the game?" "Did you feel bored with the game?" (reverse-coded), and "Do you wish you were doing something else?" (reversed). See Appendix A for the entire survey instrument. Engagement was a superordinate construct composed of the interest, enjoyment, and concentration constructs, consistent with a variety studies of engagement in learning from the perspective of flow theory (Shernoff, 2013).

2.2. Validity and reliability

The primary analytic technique utilized was Structural Equation Modeling (SEM; see Anderson & Gerbing, 1988; Nunnally, 1978; Hair, Black, Babin, & Anderson, 2010). SEM provides the possibility to run multivariate, multilevel analysis (including mediated effects) and, thus, permits modeling more complex models than traditional regression analyses (Bagozzi & Yi, 2012). Furthermore, SEM can appropriately model latent psychometric variables.

The model-testing was conducted via the component-based Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS 2.0 M3 (Ringle, Wende, & Will, 2005). Compared to co-variance-based structural equation methods (CB-SEM), the key advantage of component-based PLS (PLS-SEM) estimation is that it is non-parametric, and therefore makes no restrictive assumptions about the distributions of the data. Secondly, PLS-SEM is considered to be a more suitable method for prediction-oriented studies (such as the present study), while co-variance-based SEM is better suited to testing which models best fit the data (Anderson & Gerbing, 1988; Chin, Marcolin, & Newsted, 2003).

Convergent validity (see Table 1) was assessed with two metrics: average variance extracted (AVE) and composite reliability (CR). All of the convergent validity metrics were clearly greater than the thresholds cited in relevant literature: AVE should be greater than 0.5 and CR greater than 0.7 (Fornell & Larcker, 1981). There was no missing data, so no imputation methods were used. We can therefore conclude that the convergent requirements of validity and reliability for the model were met.

Discriminant validity was assessed, firstly, through the comparison of the square root of the AVE of each construct to all of the correlations between it and other constructs (see Fornell & Larcker, 1981), where all of the square roots of the AVEs should be greater than any of the correlations between the corresponding construct and another construct (Jöreskog & Sörbom, 1996; Chin, 1998). Secondly, in accordance with the work of Pavlou, Liang, and Xue (2007), we determined that no inter-correlation between constructs was higher than 0.9. Thirdly, we assessed the discriminant validity by confirming that each item had the highest loading with its corresponding construct. All three tests indicated that the discriminant validity and reliability were acceptable. In addition, in order to reduce the likelihood of common method bias, we randomized the order of the measurement items on the survey to limit the respondent's ability to detect patterns between the items (Cook, Campbell, & Day, 1979). Common method bias refers to a situation where there is "variance that is attributable to the measurement method rather than to the constructs the measures represent" (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003).

The sample size satisfies different criteria for the lower bounds of sample size for PLS-SEM: 1) ten times the largest number of structural paths directed at a particular construct in the inner path model (therefore, the absolute minimum sample size threshold for the model in this study would be 40) (Chin, 1998); 2) according to Anderson and Gerbing (1988), a threshold for any type of SEM is approximately 150 respondents for models where constructs comprise of three or four indicators; and 3) the sample size also satisfies stricter criteria relevant for variance-based SEM; for example, Bentler and Chou (1987) recommend a ratio of 5 cases per observed variable (therefore, the sample size threshold for the model in this study would be 95).

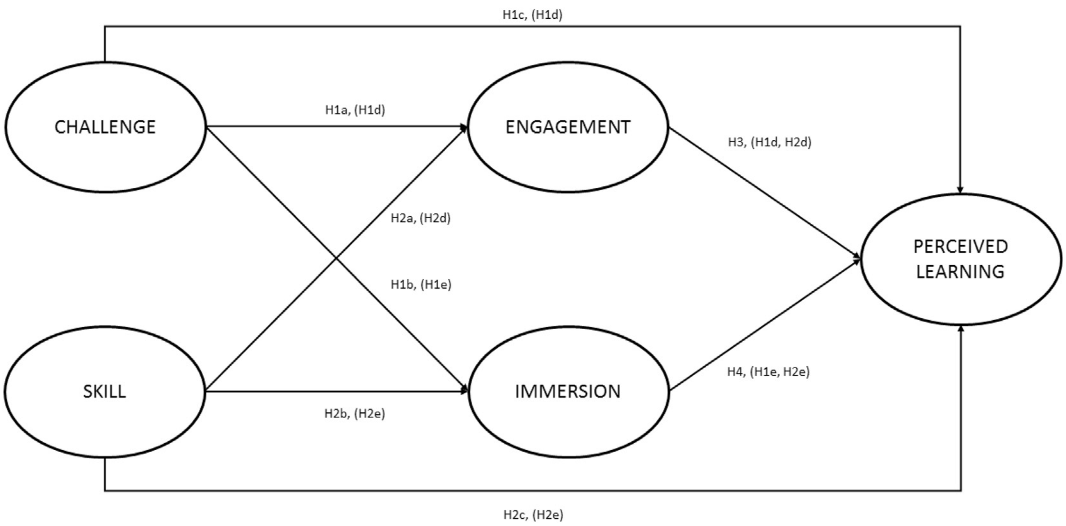

Fig. 1. Research hypotheses.

H1a: Challenge will have a positive direct effect on engagement.
H1b: Challenge will have a positive direct effect on immersion.
H1c: Challenge will have a positive direct effect on perceived learning.
H1d: The effect of challenge on perceived learning will be partially mediated by engagement [both mediated and direct effect will exist].
H1e: The effect of challenge on perceived learning will be partially mediated by immersion [both mediated and direct effect will exist].
H2a: Skill will have a positive direct effect on engagement.
H2b: Skill will have a positive direct effect on immersion.
H2c: Skill will have a positive direct effect on perceived learning.
H2d: The effect of skill on perceived learning will be partially mediated by engagement [both mediated and direct effect will exist].
H2e: The effect of skill on perceived learning will be partially mediated by immersion [both mediated and direct effect will exist].
H3: Engagement is positively associated with perceived learning.
H4: Immersion is positively associated with perceived learning.

3. Results

Results indicate that the conditions of flow (challenge and skill) accounted for 47.8% of the variance of engagement, and 50.8% of the variance of immersion. In turn, flow conditions (challenge and skill) and the experience of being in flow (engagement and immersion) accounted for 59.5% of the variance of perceived learning.

The direct effects between the variables in the path model are depicted in Fig. 4, and the total effects are reported in Table 2. Pertaining to hypotheses (H1a and H1b) related to the effect of challenge on engagement and immersion, both hypotheses were

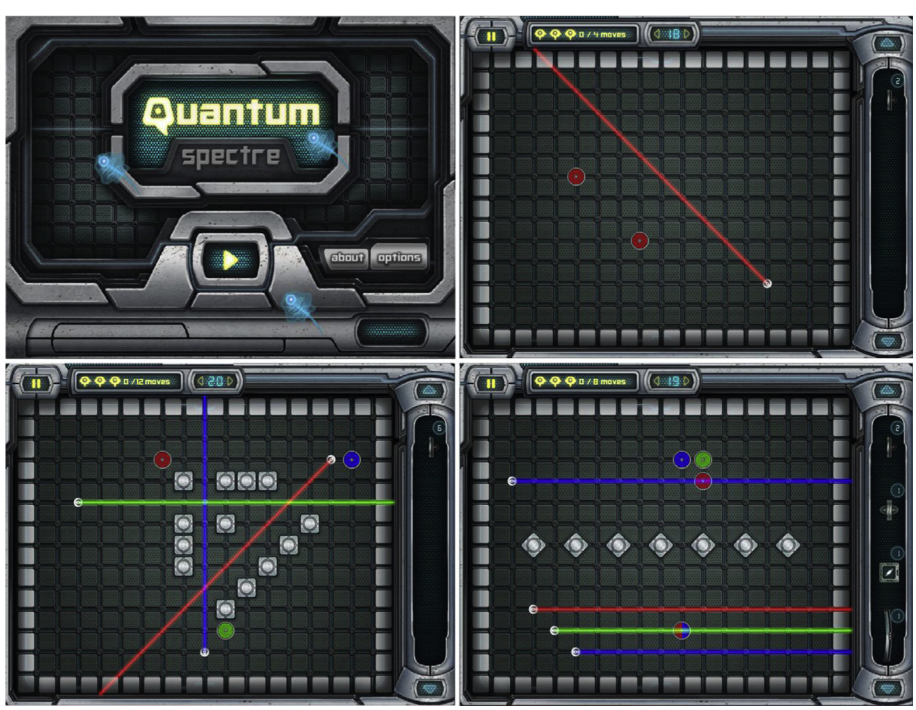

Fig. 2. Quantum Spectre screenshots.

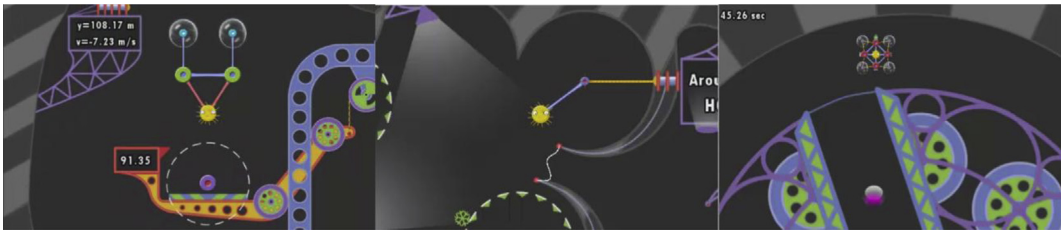

Fig. 3. Spumone screenshots.

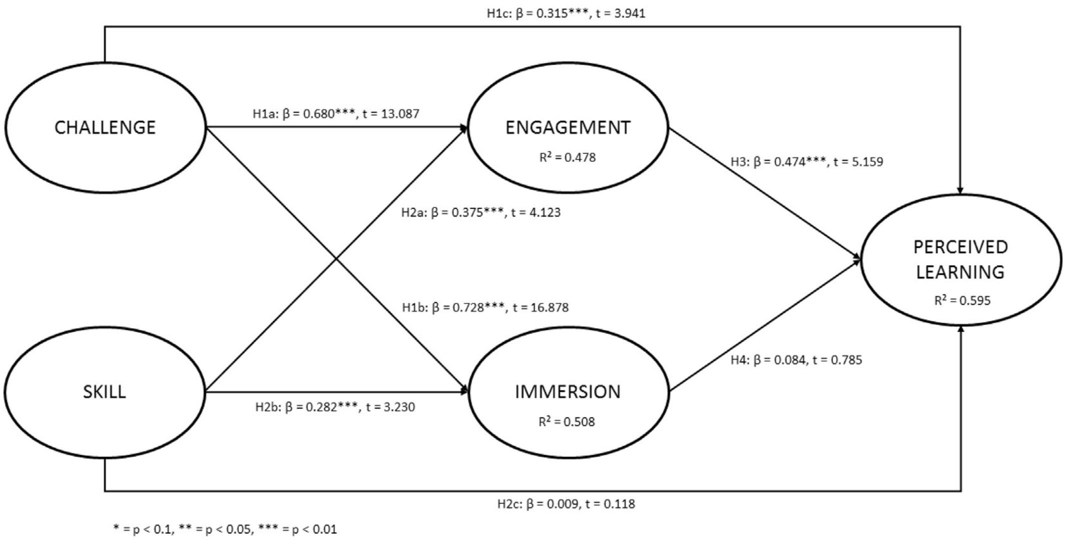

Fig. 4. Results of the path model analysis.

supported. The path coefficient between challenge and engagement was 0.680***, and 0.728*** between challenge and immersion. Expectedly, both path coefficients were high. With respect to the hypotheses pertaining to the effect of challenge on perceived learning (H1c, H1d, H1e), analyses yielded less expected results. Firstly, challenge did have a direct effect on perceived learning (H1c: 315***) as well as a mediated effect through engagement (H1d: total effect as mediated by engagement was significantly larger than direct effect). However, the effects of challenge were not mediated by immersion (H1e: no significant path coefficient between immersion and perceived learning) (see Table 3 for a summary of the hypothesis testing).

Pertaining to similar hypotheses for the effects of skill, there was a significant path coefficient between skill and engagement (H2a: 0.375***), as well as between skill and immersion (H2b: 0.282***). However, as opposed to the effects of challenge, skill did not have a significant positive direct effect on perceived learning (H2c: 0.009). However, the effects of skill on perceived learning were mediated by engagement (H2d: total effect on perceived learning 0.209***) but not by immersion (H2e: no significant path coefficient between immersion and perceived learning).

With regards to the hypotheses among engagement, immersion and perceived learning, the analyses gave support for the hypothesis that engagement has a positive direct effect on perceived learning (H3: 0.474***), whereas the results showed that there is no significant effect between immersion and perceived learning (H4: 0.009).

Results of the total effects are included in Table 2.

4. Discussion

In this study, we investigated the impact of flow (operationalized as heightened challenge and skill), engagement, and immersion on learning in game-based learning environments. Overall, the study suggests that educational video games can effectively engage students in a learning activity, as demonstrated by heightening levels of engagement (concentration, interest, and enjoyment), and that this may be activated by increasing levels of challenges and skill during game play. The results specifically showed that engagement in the game had a positive effect on learning. Immersion in the game, on the other hand, did not have a significant effect. The perceived challenge of the game affected learning, both directly and via the increased engagement. Challenge was an especially strong predictor of learning outcomes. Perceived skill did not affect learning directly, but it also impacted learning via a significant mediation effect through engagement. The hypothesized

Table 1
Validity and reliability.

	AVE	CR	PL	ENG	IMM	CHA	SKILL
Perceived Learning	0.805	0.925	**0.897**				
Engagement	0.563	0.910	0.719	**0.750**			
Immersion	0.708	0.879	0.632	0.724	**0.841**		
Challenge	0.768	0.869	0.645	0.588	0.659	**0.876**	
Skill	0.744	0.897	0.037	0.208	0.101	−0.247	**0.863**

Square roots of AVEs are reported in bold in the diagonal.

Table 2
Direct and total effects on perceived learning.

DV = perceived learning	Direct effect		Total effect (direct and mediated – See Fig. 4)	
	Beta	t-value	Beta	t-value
Challenge	0.315***	3.941	0.695***	12.618
Skill	0.009	0.118	0.209***	2.447
Engagement	0.474***	5.159	Same as direct	Same as direct
Immersion	0.084	0.785	Same as direct	Same as direct

* = p < 0.1, ** = p < 0.05, *** = p < 0.01.

Table 3
Confirmation of hypotheses.

	Description	Proof	Support
1a	Challenge has a positive direct effect on engagement	Positive Sig. coefficient	Yes
1b	Challenge has a positive direct effect on immersion	Positive Sig. coefficient	Yes
1c	Challenge has a positive direct effect on perceived learning	Positive Sig. coefficient	Yes
1d	The effect of challenge on perceived learning is partially mediated by engagement (both mediated and direct effect exist)	Total effect grows significantly when compared to direct effect only	Yes
1e	The effect of challenge on perceived learning is partially mediated by immersion (both mediated and direct effect exist)	No Sig. positive mediation through immersion since immersion has a Non-sig. small effect on perceived learning	No
2a	Skill has a positive direct effect on engagement	Positive Sig. coefficient	Yes
2b	Skill has a positive direct effect on immersion	Positive Sig. coefficient	Yes
2c	Skill has a positive direct effect on perceived learning	Non-sig. coefficient	No
2d	The effect of skill on perceived learning is partially mediated by engagement [both mediated and direct effect exist]	Non-sig. direct effect although there is a positive mediation	No – The effect is fully mediated rather than partially (also since hypothesis 2e could not be supported)
2e	The effect of skill on perceived learning is partially mediated by immersion [both mediated and direct effect exist]	No Sig. positive mediation through immersion since immersion has a Non-sig. small effect on perceived learning	No
3	Engagement is positively associated with perceived learning	Positive Sig. coefficient	Yes
4	Immersion is positively associated with perceived learning	Non-sig. coefficient	No

model explained a relatively large portion of the variance of the dependent variables. Overall, not only were most of the measured constructs significantly related to each other and engagement in the hypothesized model; but they also appeared to have a great impact on the perceived learning.

In the present study we found that both conditions for flow (i.e., challenge and skill) and engagement had a positive association with learning. These findings corroborate and build on previous studies of flow in game-based learning. For example, Hou (2015) found that flow affected student's learning behavior patterns related to in-depth reflective processes; Brom et al. (2014) found that flow is related to positive affect and both further to learning gains; and Hung et al. (2015) found that students in a tablet PC game condition achieved better flow experience, performance and satisfaction. Accordingly, much of the literature indicates that game-based learning solutions can have a positive effect on learning via flow. Prior research has also shown that challenge and skill are salient factors leading to the overall flow experience (Hamari & Koivisto, 2014; Procci et al., 2012; Wang & Chen, 2010).

Previous studies investigating immersion in game-based learning have found that game immersion did lead to higher gaming performance. Moreover, performance has been found to mediate the effect of immersion on science learning (Cheng et al., 2015). In the present study immersion did not have significant relationship with perceived learning. The lack of association between immersion and perceived learning may be caused by several factors. Immersion can be regarded as a manifold construct, conceptualized in terms of sensory immersion, challenge-based immersion and imaginative immersion (Ermi & Mäyrä 2005). In this study, we did not employ refined enough measurement to make a distinction between the different types of immersion. Further investigation of this possibility affords a fruitful avenue for further research. Consequent studies on immersion and learning should more deeply measure immersion and the effect of different types on learning. For example, the more sensory or imaginative immersion types could intuitively be less associated with learning, whereas the challenge-based immersion may present a more of a cognitive-rational type of immersion more associated with learning. Moreover, neither of the games included in this study, *Spumone* nor *Quantum Spectre*, involve a narrative driven, avatar-based, sensory or imaginative immersive experience that other games may provide. Players may be engrossed in the challenge of solving the puzzles, which relates more to their sense of cognitive engagement than immersion. Further studies using 3D immersive games, such as games in virtual worlds with avatars and a detailed environment, would be helpful to explore this possibility further.

Another interesting finding from this study was that challenge and skill behave differently with respect to predicting perceived learning: challenge has a direct and a mediated effect (through engagement) on perceived learning, whereas skill only has a mediated effect. This implies that the entire effect of skill is mediated by engagement whereas for challenge, there is some portion of its effect that is separate from increasing engagement. The questions remain: 1) how does challenge predict perceived learning in a way that is not related to engagement? and 2) why does not skill have the same effect? These results affords further study on the relationship between these factors in game-based and other learning environments. Generally, flow theory would predict that only optimally challenging tasks would have a positive effect on learning as through positive engagement (Shernoff, 2013). However, it could be the case that a level of challenge that rises above the 'optimal' state of flow, by exceeding the learners' skill, may be an important precursor to learning (Reese, 2015). In this case the challenge might increase learning because the student has to apply a wider range of strategies in order to solve the puzzle in the game. As the player uses both trial-and-error and premeditated strategies instead of breezing through the tasks, his or her subjective state may feel more like anxiety or arousal than engagement. Thus, research is beginning to converge on the possibility that anxiety and arousal are important precursors to both learning and flow (which is reached as players increase in skill).

The relationship of engagement and perceived learning in the game-based context may be further explained by the phenomena of indwelling, where students' ongoing engagement and immersion in gameplay may support tacit knowledge development of the scientific principles targeted by the game (Asbell-Clarke, Rowe, & Sylvan, 2013). Serious games present the opportunity for indwelling, when familiarity with ideas, practices, and processes are so ingrained that they become second nature. However, because these ideas, practices, and processes are components of tacit knowledge, they are difficult to measure. Game-based tacit learning, however, can be leveraged by educators when teaching related content in class. This implication was corroborated by the present study in addition to a previous study of high school science teachers who used examples from free-choice science games while teaching Newton's first and second laws. The study found gains on related pre/post tests in these classes as compared to classes that did not play the game or did not receive game-based examples during instruction, with the largest differences observed in non-AP/Honors classes (Rowe, Asbell-Clarke, Bardar, Kasman, & MacEachern, 2014).

4.1. Limitations of the study and future directions

As is commonplace with studies conducted by cross-sectional online surveys, the data in this study were self-reported. A further methodological step would be to combine survey data with game log data and assessments in order to increase the robustness of the measurement. As data mining methods advance to reveal and measure implicit knowledge and skill, knowledge and skill that players demonstrate though gameplay may become increasingly illuminated. Researchers collect gameplay data in conjunction with pre-post game assessment in order to study the relationship between how gameplay relates to improvement in knowledge or understanding. These results could further be compared to the self-reported survey data to examine the degree to which their self-reported levels of learning correspond with learning as evidenced by their gameplay patterns and responses to the assessment items. Future studies could also employ techniques such as “think alouds” during game play, video analysis, click-data, eye-tracking analyzed all in conjunction to gauge the state-to-state experience of the student while playing the game.

This study was conducted in the context of games related to physics. While there are no a priori obvious reasons to expect that this context would have an effect on the results, it is feasible that results may vary between different kinds of platform and subjects. Herein the games were 2-dimensional, ‘error and trial’-oriented, and the games provided a clear goal (in contrast to more free-form playing). Further studies might investigate the influence of these factors further.

Student factors might further moderate the results of a study such as this one. Further studies could investigate whether these results differ by demographic factors, gaming orientations, degrees of interest towards the study subject, and so forth. For example, prior studies have demonstrated individual differences in how the benefits of game-based technologies are perceived (Koivisto & Hamari, 2014). Therefore, further studies could investigate the moderating role of, for example, personality differences (McCrae & John, 1992) and playing orientations (Yee, 2006; Hamari & Tuunanen, 2014). Furthering this line of research could refine our understanding of what kinds of game-based learning implementations are more likely to be suitable for certain learning environments and certain kinds of learners.

4.2. Contribution and implications of the study

This study examined conditions for flow (i.e., challenge and skill), engagement, immersion, and learning in games, because they are important dimensions of learning suggested throughout psychological and cognitive-based research. The study sought to build on prior literature on game-based learning literature that has investigated learning, flow and engagement (e.g. Admiraal et al., 2011; Akkerman et al., 2009; Brom et al., 2014a; 2014b; Byun & Loh, 2014; Coller & Shernoff, 2009; Deater-Deckard et al., 2014; Eseryel et al., 2013; Hou, 2015; Hou & Li, 2014; Huizenga et al., 2009; Hung et al., 2015; Liu et al., 2011; Pellas, 2014; Proske, Roscoe, & McNamara, 2014; Ronimus et al., 2014; Sabourin & Lester, 2014; Tüzün et al., 2009; van der Spek et al., 2013; Wang & Chen, 2010). To this vein of literature, the present study suggests that educational video games can indeed be an effective means of creating conditions for flow, heightened engagement (including interest, concentration, as well as enjoyment), and immersion, which can further facilitate the learning of complex strategies through game-based learning. The present study also contributes to the growing body of literature in larger domain of gamification where similar factors have been investigated both within and outside the domain of education and learning (e.g. Domínguez et al., 2013; Hamari, 2013, 2015; Hamari & Koivisto, 2014; 2015a; 2015b; Hakulinen, Auvinen, & Korhonen, 2015; Hanus & Fox, 2015; Lieberoth, 2015; Simões, Díaz Redondo, & Fernández Vilas, 2013).

This study contributes to literature on game-based learning by demonstrating that educational video games may be an effective means of posing learning challenges that are perceived as interesting and enjoyable, resulting in engagement and immersion in the game-based learning task. Thus, the challenge created by the game appears to be an important antecedent for engagement, and essential for learning through the game. These findings suggest that game designers should emphasize challenge and engagement while considering players' skills, which we found also to contribute to engagement and immersion. Vygotsky (1978) believed that learning occurred within a learner's Zone of Proximal Development (ZPD), the range of activities from that which a learner can master independently to that which can be accomplished with the help of additional supports or scaffolds. Offering activities that are in the players' ZPD will challenge learners within the range appropriate to their skill level, thus keeping them maximally engaged and learning.

Games afford a great deal of individualized customization in terms of matching the challenges of the learning activity to a players skills as they progress. Results imply that the challenge of effective educational game design is for games to keep pace with the learner's growing abilities in order to facilitate continued learning in game-based learning environments. Through play-testing, game designers can establish a range of activities within the ZPD of their target audience with adjustable levels of challenge (see e.g. Chanel, Rebetez, Bétrancourt, & Pun, 2011; Liu, Agrawal, Sarkar, & Chen, 2009; Qin, Rau, & Salvendy, 2010), and provide appropriate scaffolds and supports (e.g., clues, resources, etc.) based on previous performance. This can continuously keep players within their ZPD and engaged in learning, helping students who tend to get bored or overwhelmed with traditional instruction active and motivated and in the learning process. Optimistically, this could result in the development of games that are adaptive and customizable for a broad and diverse audience of learners.

Such affordances of well-made games are especially important in an era of educational policy emphasizing standards and assessment with a “one-size-fits all” mentality that has been observed to neglect both individualization and engagement in instruction. Such an approach achieves efficiency, especially in its ability to sort students and teachers, but is not learner-centered. The present study supports game-based learning as an educational approach that flips this paradigm on its head, positing that engagement is a critical aspect of learning. In order for this approach to succeed widely, the influence of games on teaching and learning will need to be approached from the domains of instruction, pedagogy, and assessment. In addition, educational policies friendly and open to games as a potentially effective educational offering are still needed. Nevertheless, the ability of high quality educational video games to pose complex problems perceived by players as at once challenging and enjoyable is a sturdy foundation on which to build.

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Appendix A. Survey instrument and factor loadings

Construct	Question	Learning	Engagement	Immersion	Challenge	Skill
Learning1	“Did you feel you were learning?”	**0.869**	0.609	0.538	0.520	0.066
Learning2	“Playing the game increased my understanding of science”	**0.918**	0.670	0.615	0.606	0.024
Learning3	“The game helped me learn”	**0.904**	0.656	0.546	0.607	0.011
Engagement1	“How hard were you concentrating”	0.510	**0.603**	0.526	0.496	0.071
Engagement2	“It provided content that focused my attention”	0.586	**0.790**	0.608	0.491	0.141
Engagement3	“How much did you enjoy what you were doing?”	0.616	**0.806**	0.62	0.416	0.336
Engagement4	“Interacting with it was entertaining”	0.507	**0.824**	0.531	0.482	0.17
Engagement5	”Interacting with it was fun”	0.567	**0.810**	0.569	0.459	0.256
Engagement6	”How interesting was the game?”	0.663	**0.855**	0.625	0.503	0.179
Engagement7 (reverse-coded)	”Did you feel bored with playing the game?”	0.382	**0.604**	0.378	0.337	−0.116
Engagement8 (reverse-coded)	“Did you wish you were doing something else”	0.395	**0.659**	0.400	0.291	0.077
Immersion1	”How immersed were you in the game?”	0.642	0.698	**0.864**	0.598	0.094
Immersion2	“I lost track of time while playing it”	0.475	0.572	**0.821**	0.501	0.145
Immersion3	“I became very involved in the game forgetting about other things”	0.454	0.539	**0.838**	0.557	0.015
Challenge1	”Was it challenging?”	0.498	0.457	0.481	**0.841**	−0.276
Challenge2	“Playing it stretched my capabilities to the limit”	0.621	0.564	0.656	**0.910**	−0.172
Skill1	“I was not very good at the game”	−0.049	0.152	−0.04	−0.288	**0.776**
Skill2	“How skilled were you at the game?”	0.047	0.163	0.121	−0.223	**0.879**
Skill3	“I was very skilled at the game”	0.060	0.214	0.124	−0.177	**0.925**

Item loadings onto the intended construct are reported in bold.

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