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Chapter 6

THE MOTIVATION AND MASTERY CYCLE FRAMEWORK: PREDICTING LONG-TERM BENEFITS OF EDUCATIONAL GAMES

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ABSTRACT

By combining the benefits from Intelligent Tutoring Systems (ITSs) and video games, educational games offer the unique potential to capture learners' interest, compel them to persist with targeted tasks, and can result in improved mastery of educational content and skills. These benefits are described within the context of educational game research and incorporated into two new potential frameworks. The potential frameworks are designed to help structure findings from various literature bases in a manner that helps to inform future system designs and illustrates possible contributions to and the importance of considering timescales for evaluating effects of educational games. Tentative empirical support for these frameworks is provided through empirical results with iSTART-ME, along with general conclusions from the research presented.

Keywords: intelligent tutoring, ITS, educational games, learning, long-term retention, motivation, engagement, persistence, game features

INTRODUCTION

Implementing computer technologies in schools is challenging (Dynarski et al., 2007), but significant progress in the quality, affordability, and distribution of education may be enhanced by our ability to leverage the advantages of such technologies. For example,

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Intelligent Tutoring Systems (ITSs) are automated learning environments that can adapt to individual students based on previously established principles and algorithms (Anderson, 1982). These systems have been successful across several decades of research and consistently produce significant learning gains across a variety of domains (Cohen, Kulik, & Kulik, 1982; Graesser, McNamara, & VanLehn, 2005; Merrill, Reiser, Ranney & Trafton, 1992). Although these systems have been successful at promoting student learning, one potential weakness of more long-term learning systems, like ITSs and other adaptive learning systems, is that the novelty of the adaptive environment wears off and some of the practice-for-mastery type of interactions can become repetitive over time, particularly if students are interacting with the system on a regular basis. This repetitive nature can cause some students to disengage, which becomes a particular problem if the targeted skill (or knowledge) requires an extended amount of practice to attain a certain level of mastery (e.g., reading comprehension, critical thinking, algebra).

The potential effects of disengagement with ITSs may not be readily apparent from the majority of prior research, primarily due to the cost and associated methodological complications of conducting long-term studies (i.e., multiple sessions across days, weeks, months, years) in comparison to the ease and methodological elegance associated with short-term studies (i.e., several minutes to a few hours). Indeed, conducting experiments to examine training for highly complex skills with skill-based tutoring systems can be costly and time intensive for researchers, teachers, and students, especially when those skills require prolonged interaction to reach mastery. Moreover, short-term studies produce valuable results for many scientific inquiries. Nonetheless, it is questionable as to whether they sufficiently address or generalize to issues and questions related to skill acquisition that may occur over extended periods such as across an academic year (e.g., real classrooms). It is important to note that several longer-term ITSs have been deployed, integrated, and evaluated within ecological settings (Jackson, Boonthum, & McNamara, 2010; Johnson & Valente, 2008; Koedinger & Corbett, 2006; Meyer, Wijekumar, & Lin, 2011). Due to the extended interactions with these systems it is likely that some students will get bored and disengage during their learning sessions (Arroyo et al., 2007; Baker, D'Mello, Rodrigo, & Graesser, 2010; Bell & McNamara, 2007). If these students do not reengage (and persist) with the learning system, then it will be difficult or impossible to achieve the long-term learning objective. Thus, it is critical for researchers to understand the time-sensitive factors that contribute to prolonged system interactions and how those relate to student learning outcomes.

To this end, recent research efforts have begun to develop a new generation of hybrid learning technologies that combine sophisticated tutoring and game-based principles (Jackson et al., 2010; Johnson et al., 2004; Millis et al., 2011; Rowe et al., 2009). Whereas ITS pedagogical principles help to maximize learning, game design and mechanics contribute to positive motivation and engagement. Thus, game-based environments should lead to improvements in student learning if one incorporates strong underlying pedagogical principles, and ITSs should be rendered more engaging by implementing inherently motivating game designs. However, this is not simply a grafting of two successful but incompatible technologies (e.g., gamifying an existing learning task by adding arbitrary points that have little to no connection to the learning or environment goals); research suggests that these technologies have a common theoretical foundation and that the sum is greater than the parts (i.e., that good learning design and good game design are aligned and complementary; Laird & van Lent, 2000; Van Eck, 2006). Indeed, one of the primary benefits to educational games is their significant overlap with sophisticated training systems in that they both provide students with the opportunity for adaptive, individualized interactions.

Although the research in this cross-disciplinary area is still relatively immature, educational games hold the promise of producing motivating, engaging, effective environments in which students will strive to provide their best performance. These systems are uniquely situated to harness the sophisticated pedagogical benefits of ITSs within motivating and engaging environments that promote enjoyable game-based interactions. Combining the learning and game based features from both approaches should lead to effective and prolonged engagement, thereby leading to sustained learning and mastery.

Some theories suggest that there is a cognitive load tradeoff between engagement and effective learning (e.g., Mayer, 2014), particularly when game components require additional attention and effort, in addition to the targeted skills or knowledge. Accordingly, games can distract from learning. In this chapter, we propose a cycle of motivation and mastery wherein this tradeoff may exist in the short-term, but may be associated with additional benefits over the long-term. As such, the timescale of learning is a critical factor when considering the benefits of educational games. To bolster the more recent work on educational games, research from related areas provides support for these claims and helps to explicate frameworks that apply to the design of environments and interpretations of outcomes.

GAME-BASED ENVIRONMENTS

In an ideal world, students who are learning or being assessed would perform at their best and seek to maximally succeed at any given task. Unfortunately, this is often not the case. Many students lack sufficient motivation or engagement when learning, and when being assessed. Hence, educators and researchers are driven to seek more innovative means to maintain learners' motivation and engagement. Many have turned to game-based environments as a solution. Games are increasingly explored as a means to improve students' desire to strive toward their optimal potential. Games can diversify educational environments and offer new methods of learning. These innovative approaches should not only help to improve the user experience, but also the underlying understanding we can glean about students. In addition to immediate effects of engagement and performance, for more long-term interactions, game-based systems have the potential to maintain learner involvement after the point when factors such fatigue or boredom might induce them to abandon a traditional learning environment (e.g., Jackson & McNamara, 2013). As such, game-based features in learning environment may help to retain students and induce them to prolong engagement in activities – enhancing the potential benefits from the learning environment.

It is generally purported that games are more engaging and have the potential to lead to better, more sustained learning when compared to other environments (Adams, Mayer, MacNamara, Koenig, & Wainess, 2012; Garris, Ahlers, & Driskell, 2002; Gee, 2003; Steinkuehler, 2006). Educational games allow an individual to engage with the necessary content and tasks while instructors are potentially able to monitor the progress of multiple simultaneous (or asynchronous) learners. Many commercial games utilize adaptive system designs that help to maintain an appropriate level of challenge and keep players engaged (e.g., *Borderlands* and similar RPG games provide items, and sometimes opponents, relative to your current character level). To accomplish this same goal, an educational game must be able to identify the ability level of the learner and adjust itself accordingly (Conati, 2002; Rieber, 1996; Shute & Towle, 2003). As such, the game may require demonstration of more advanced skills or knowledge from a player who is progressing successfully through the game, or lessen the requirements for a player progressing poorly. Additionally, rapid feedback within educational games can help players to better regulate their progress and activities, and feedback in any educational environment can significantly improve engagement (Anderson, Corbett, Koedinger, Pelletier, 1995; Corbett & Anderson, 1990; Foltz, Gilliam, & Kendall, 2000). To a greater extent than traditional educational systems, games are designed to render interactions more enjoyable, thus leading to greater perseverance and enhanced motivation to engage with the system.

Beyond their effects on student enjoyment and engagement, game-based environments can also fulfil a number of educational and pedagogical roles (Gredler, 2004). Indeed, there are many efforts that leverage the potential roles of games to cover a wide range of academic content and goals (for reviews see Clark, Nelson, Sengupta, & D'Angelo, 2009; Clark, Tanner-Smith & Killingsworth, 2014; Young et al., 2012) (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010; Dede & Barab, 2009; Jackson, Boonthum, & McNamara, 2009; Rosenbaum, Klopfer & Perry, 2007; Rowe, Shores, Mott, & Lester, 2011; Squire & Jan, 2007). Game have been used for the acquisition of new knowledge or as a practice environment, where the game required repeated application of the relevant knowledge across a variety of contexts (Orbach, 1979; Shank & Neaman, 2001). Games have also been used as assessments, in which the game is used to evaluate a learner's ability to apply knowledge and skills (Bertling, Jackson, Oranje, & Owen, 2015; Shute, Ventura, Bauer, & Zapata-Rivera, 2009; Zapata-Rivera, Vanwinkle, Doyle, Buteux, & Bauer, 2009). Games have been used for formative and/or summative purposes, where the system provides a venue to apply a variety of skills, which can be assessed and scored (Bauer et al., submitted). Similarly, educational games can provide a means for learners to refine and combine existing knowledge, affording opportunities to explore novel combinations of existing knowledge and, in turn, the development of a better understanding of relations between concepts (Swaak & de Jong, 2001).

Gaming environments differ widely, ranging from incorporating points accrued within traditional tutoring environments to full-fledged games with narration, embedded worlds, beginning and end states, interactions, rules, and reward systems (Gee, 2003; Rieber, 1996; Ritterfeld & Weber, 2006). Researchers have investigated the complex forms of participation and learning that can occur during game play, highlighting various learning affordances such as rich perception–action cycles, collaborative inquiry, and exploration of identities (Gee, 2003; Shaffer, Squire, Halverson, & Gee, 2005; Squire, 2006; Steinkuehler, 2006). Some games have the potential to provide entire worlds designed to help learners adopt roles and engage story lines previously inaccessible to them. If properly designed, games can provide the problems, tools, experiences, and consequences to foster the development of rich content understanding (Barab, Gresalfi, & Arici, 2009).

Well-designed games are appealing to players because they address their affective states, motivation, and expectations (O'Neil, Wainess, & Baker, 2005). One thing that games offer, as opposed to other educational settings, is that they provide various engagement levers that compel the player to progress. Beyond the entertainment value, most contemporary videogames require players to do more than mindlessly click buttons. Rather, many games call on players to employ complex discursive practices and problem solving strategies as they come to master and appreciate the underlying game dynamics (Gee, 2003; Shaffer, 2007). In essence, a detached or distracted player runs the risk of losing the game and missing out on additional enjoyable experiences. Unfortunately, engagement cannot be guaranteed simply because a game is present. The player must want to play it for a game to be effective. Interest in the actual content of the game is a preferred method of obtaining engagement, but not all players share interests. While the content matter is important for determining interest, perhaps the framing and difficulty of the content is more critical to sustain student engagement over time.

In addition to the game content being important, to maintain prolonged engagement, the system must be optimally challenging (Gredler, 2004; Malone, 1981; Rieber, 1996). Easy games require little effort or engagement from players while overly difficult games can inhibit interest because players are unable to accomplish goals. Methods to adapt challenge can be achieved through superficial, off-task design features (e.g., increasing the speed of on-screen elements, obscuring information) or deeper construct-relevant features (e.g., more difficult content, systems of interactions). The latter approach has implications for educational game designers, especially as it relates to the zone of proximal development (ZPD) (Malone & Lepper, 1987; Rieber, 1996). Vygotsky (1978) posited that knowledge acquisition is most effective when the material is slightly more advanced than the learner. This hypothesis is not limited to traditional educational tasks, but also applies to educational game design. Games at the zone of proximal development offer the appropriate level of challenge and may sustain interest and engagement by providing accomplishment while maintaining effort.

The synthesis of powerful pedagogical principles and effective game design may have the power to promote and sustain motivation, engagement, and persistence, and as a result, improve the quality of educational environments. Indeed, individual studies have shown positive learning and motivational outcomes (Jackson & McNamara, 2013; Ricci, Salas, & Cannon-Bowers, 1996; Rowe et al., 2011), and meta-analyses have reported that across groups of people (e.g., gender, age), interactions with games can lead to better outcomes for cognition, improved skills, and positive affect (Vogel et al., 2006; Wilson et al., 2009).

The Impact of Students' Motivation, Engagement, and Persistence

Ample research shows that learning is more than just a cognitive process (du Boulay, 2011); learning is as much a motivational and affective task as it is a demonstration of mental ability. For the current purposes, motivation is considered to be a multidimensional construct that subsumes a number of component factors, such as interest, enjoyment, expectancies, and values. In this sense, motivation generally refers to students' desire to perform a task and willingness to expend effort on that activity (Garris et al., 2002; Pintrich & Schrauben, 1992; Wolters, 1998).

While not a main focus here, it is important to note that researchers have historically distinguished between two forms of motivation: extrinsic and intrinsic. Extrinsic motivation is viewed as performing a given task in order to receive an external reward (e.g., points, trophies, praise, and money), and is relatively facile to implement within a learning environment. Such motivation often succeeds in inducing students to perform well on an assigned task. However, overemphasis of extrinsic motivators has also been linked to decreased intrinsic motivation in the target activity (Morgan, 1984). Intrinsic motivation is conceptualized as performing a given task because of an inherent personal interest in that activity (e.g., hobbies). Intrinsic motivation is difficult to manipulate within a learning environment, but is typically related to increased on-task performance and long-term retention (Malone & Lepper, 1987; Tobias, 1994).

Most educational game researchers generally assume that games improve students' motivation or engagement (among other things), and increased engagement enhances learning outcomes. When students are not engaged, they are more likely to be bored or inattentive; neither being conducive to learning. For example, Craig et al., (2004) found that higher levels of boredom while learning with an ITS correlated negatively ($r = -0.39$) with learning, whereas flow (or engagement) was positively correlated with learning ($r = 0.29$). Bored learners are more likely to bypass the system (Rodrigo et al., 2007). Boredom may also trigger a vicious cycle that can prevent students from actively reengaging in constructive learning processes (Boekaerts, Pintrich, & Zeidner, 2000; D'Mello & Graesser, 2006; D'Mello, Taylor & Graesser, 2007).

Thus, in order to produce effective outcomes with educational systems, it is important to keep learners focused and interacting with the target activities throughout training and practice. For a longer-term interactive system, requiring sustained interactions across time and where improvements are expected to occur across multiple stimuli or sessions, there are two primary constructs (relevant to game-based systems) that significantly support growth towards mastery: *engagement* and *persistence*.

Engagement

Engagement can be understood as the extent to which a person is involved in an activity and focuses attentional resources on that task. Research suggests that learning improves as the depth of cognitive engagement increases, and greater engagement during learning improves retention (Hannafin & Hooper, 1993). A deeply engaged person may even become unaware of stimuli outside of the current activity. In the game literature, engagement is considered the sine qua non of a successful videogame, although there is a lack of agreement about how to label subjective experiences during gameplay (Wirth et al., 2007) and a limited understanding of how specific game features interact with player characteristics to promote engagement.

The terms immersion and flow have been used most often to conceptualize different levels of game engagement. Immersion describes a level of medium engagement wherein players become focused on the game-playing experience while retaining awareness of their surroundings (Baños et al., 2004; Singer & Witmer, 1999). By comparison, the term flow is often used to describe deeper engagement that occurs when there is a balance between skill, challenge, and intrinsic reward while performing an activity, and awareness of the outside world may fade into the background (Csikszentmihalyi, 1990; Moneta & Csikszentmihalyi, 1996; Moneta & Csikszentmihalyi, 1999).

As measured by subjective questionnaires, many off-the-shelf entertainment games foster high levels of engagement. As a result, instructional designers are currently attempting to identify and borrow techniques from game design to apply to educational media. Video games that provide specific goals and immediate performance feedback structure can increase flow, which has been associated with enhanced learning (Gee, 2005). It has been measured more specifically in recent work by Reese and colleagues (Reese, 2010), who have demonstrated that flow can be precisely measured during gameplay, used to manipulate game complexity, and that it is directly related to learning and assessment. If educational game designers wish to understand and achieve the same level of engagement found in entertainment-oriented games, further research is needed to systematically examine how game features interact with player characteristics to promote engagement while still maintaining high pedagogical standards.

Persistence

Persistence can be defined as the continued enactment of or engagement in a particular task or activity, particularly in the face of obstacles or failure. Unfortunately, a common challenge encountered in long-term practice is maintaining students' active involvement and mental engagement with the learning activity. This problem can particularly arise for educational systems that require long-term tutorial interactions spanning days, weeks, or even months. These environments can struggle to maintain student interest over time due to the repetitive nature of practice tasks. However, learning and mastering a new skill requires significant effort and practice over an extended time period (Anderson, Conrad, & Corbett, 1989; Newell & Rosenbloom, 1981). Skill acquisition can involve several stages of mastery: focusing on individual principles or strategies, combining those principles into a collection of interacting components, and extended practice to increase the speed and accuracy of applying the skill (Van Lehn, 1996). Thus, persistence is a critical component for students to improve skills, especially for complex cognitive skills (e.g., text comprehension or systems thinking). The emphasis on persistence is aligned both with traditional pedagogical goals and educational gaming environments. Previous research within educational games indicates that "persistent reengagement" is crucial to instructional design and is a desired state for educational game developers (Garris et al., 2002).

MOTIVATION AND MASTERY IN GAME-BASED LEARNING ENVIRONMENTS

McNamara, Jackson, and Graesser (2010) described a new generation of learning technologies emerging from hybrid systems that combine intelligent tutoring and games, which they dubbed Intelligent Tutoring and Games (ITaG). To capture the literature linking game-based features to constructs related to motivation (briefly described in the previous sections), they proposed a framework to classify game-based features into five broad categories, including *feedback*, *incentives*, *task difficulty*, *control*, and *environment*. As shown in Table 1, they provided a non-exhaustive list of game-based features for each of these five categories and motivational constructs that might be affected if the feature were added to an ITS.

Table 1. Categories of game-based features, their function, and the motivational construct expected to be most influenced by adding the feature to an ITS from McNamara, Jackson, and Graesser (2010). Copyright © 2010, IGI Global

Category	Enhancement Features	Function	Motivational Construct
Feedback	Verbal information, consequences, points, progress bar, skillometer, levels	Information regarding the accuracy or quality of responses is provided to the student	self-regulation, self-efficacy
	Competition	Information is provided on performance relative to others	self-regulation, self-efficacy, interest, engagement
Incentives	Points, levels, skill bar	Student acquires points or advances in levels by completing tasks successfully	self-regulation, self-efficacy, engagement
	Mini-games, exchange or modify avatar or environment	Student provided with motivational hooks (e.g., play game, change features of environment)	self-efficacy, interest, engagement
Task Difficulty	Tasks or materials vary in difficulty, task requirements gradually increase in mini-games	ZPD: Task or material is appropriately challenging and scaffolded according to Zone of Proximal Development (ZPD)	self-efficacy, engagement
	Tasks or materials vary in difficulty	Backsliding: Student is given easier task after failure	self-efficacy
	Tasks or materials vary in difficulty; feedback varies according to performance history	Empowerment: Task is conveyed as difficult, but is below ZPD	self-efficacy
Control	Choosing rewards: mini-game, character, color	Student controls aspects of environment	self-regulation, self-efficacy, interest, engagement
	Levels, points, tasks, materials (e.g., texts), rewards (change agent/color)	Student sets goals or subgoals to complete	self-regulation, self-efficacy, interest, engagement
Environment	Game-like environment, changeable colors, icons, aesthetically pleasing backgrounds	ITS is set in a (more) appealing environment	interest, engagement
	Animated agents or avatars	Animated agents improved/incorporated	interest, engagement
	Multi-media: mini-games, graphics, video, simulations,	Simulations and other multimedia improved/incorporated	interest, engagement
	Narrative, immersive environment, fantasy	Game revolves within a narrative or immerses the learner within an environment simulating the real world or depicting fantasy	interest, engagement

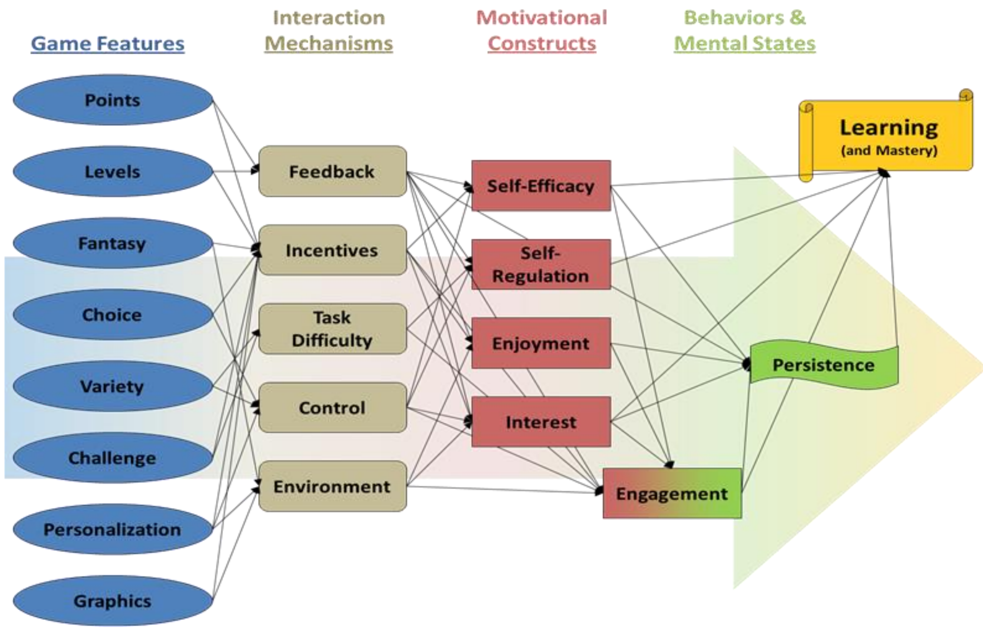

Figure 1. Mapping between elements, mechanisms, constructs, behaviours, and learning.

Previous research additionally suggests indirect links between motivation and learning (Garris et al., 2002); namely, motivation influences the learning processes that students utilize (e.g., strategies employed), which subsequently affect learning outcomes. There is little evidence that motivation, per se, directly impacts knowledge acquisition or comprehension; but there is a good deal of evidence for indirect connections. In this chapter, we have visually illustrated in Figure 1 the framework proposed by McNamara et al., (2010; Table 1) in combination with potential links to learning and mastery. This provides a non-exhaustive visual mapping of empirically supported links, extending from example game features through interaction mechanisms to motivational constructs, which in turn influence behaviours and mental states that support learning and mastery.

The left column of Figure 1 displays a non-exhaustive list of a few common game features described in Table 1. These features were selected based on their inclusion in several different empirical evaluations across both game and non-game environments. Thus, they are not intended as an exhaustive or definitive list of potentially impactful design features, but rather serve as empirically supported exemplars for explanatory purposes. Many games (and educational systems) leverage these, and other, features as part of the core system design. None of these individual features are required within a game, but previous research has suggested that the affective benefits from games may increase linearly as the number of incorporated game-based features also increases (Cordova & Lepper, 1996; Papastergiou, 2009). Therefore, we could imagine that combining several game features together could provide students with a more enjoyable and engaging interaction.

Game features can be integrated into an environment in a variety of ways. For example, points can be awarded for any number of actions, and their scale of measurement can range from negative values up to infinity. Regardless of implementation, the presence of points provides the learner with some degree of feedback (i.e., more or fewer points equates to better or worse performance depending on the goal of the game). Thus, points in any form can function as a form of feedback. This broader function of feedback is represented in Figure 1 as the connection between "points" in the first column and "feedback" in the second column.

This second column in Figure 1, interaction mechanisms, provides mappings from the various game features to common functions. Other relations, for example, include a) personalization as an incentive, b) the variety of options as a source of control, c) in-game challenges to afford task difficulty, and d) the quality of graphics as it affects the environment. These example features potentially serve multiple functions within a system, and likewise, mechanisms may be implemented through a variety of features. For this reason, Figure 1 includes multiple links from each feature in Column 1 and multiple links to each mechanism in Column 2. Although we expect that specific features can have particular impacts on an individual's game experience, it is unlikely that adding in individual game features to an ITS will result in an experience of playing a game (Davis, Jackson, & McNamara, 2010). We suspect that a coherent and complete game experience requires multiple interaction mechanisms. Additionally, it is important to note that these features may be highly interrelated and may have different relative, and potentially interdependent effects. For example, points may be used as a way to increase in levels, which may be how challenge and task difficulty are determined, which may (or may not) have a stronger link to engagement than the aesthetics of a graphical environment. As such, the framework in Figure 1 is intended to illustrate that features, or sets of features, can be conceptualized as specific instantiations and contributors to latent categories of interaction mechanisms whereby learners affect changes in the environment. It is not feasible to draw lines between every potential relation as some combinations are appropriate in one context, but not in another. Additionally, the consistent size of objects within the figure is not an indicator of strength, value, or anything else. The strength and impact of a particular feature or set of features would depend on specific implementations within an environment. Thus, we are not attempting to make any a priori claims about how features may be more or less important. Rather the goal is to illustrate the notion that the features selected for a given environment design impact important constructs related to motivation and education. Thus, it is critical for designers and educators to keep these implications in mind when designing an environment. Figure 1 may suggest that by adding more features across different types of categories you may produce larger effects on the related constructs; however this effect is implied and there is not current research to support that implication.

The third column of Figure 1 provides a selected list of extensively researched constructs related to motivation. The particular constructs included here are not meant to be exclusive or exhaustive, but rather were selected as examples based on their inclusion across a large number of game and non-game research, including areas of education, psychology, game design, and human-computer interaction. Research from a variety of domains has thoroughly examined how the interaction mechanisms from Column 2 affect these motivational constructs. For example, across the top of Figure 1, there is abundant research in the cognitive area that has shown that various dimensions of feedback (structure, content, schedule, and delivery method) have a profound impact on the learning process and can influence both students' self-efficacy and self-regulation (Anderson, Corbett, Koedinger, & Pelletier, 1995; Corbett & Anderson, 1990; Foltz et al., 2000; Jackson & Graesser, 2007; Schunk & Pajares, 2001; Shute, 2008). Other examples from research have shown that incentives increase enjoyment (Moreno & Mayer, 2005), changing task difficulty can affect self-regulation (Boekaerts & Cascallar, 2006; Schunk & Pajares, 2009), and providing control can improve interest (Cordova & Lepper, 1996). Similar to the connections between the first two columns, there are multiple links from each mechanism in Column 2 and there are multiple links to each construct in Column 3. The multiple mappings between columns reflect the varied and complex relations between these concepts and suggests that combinations of interaction mechanisms will likely have profound effects on the various motivational constructs.

Research has also shown that the motivational constructs within Figure 1 have an effect on students' behaviours, mental states, and learning. As such, we propose that motivation influences the learning processes that students utilize (e.g., strategies employed), which subsequently affect learning outcomes (albeit indirectly). For example, research has shown that self-efficacy is positively related to students' persistence and academic outcomes (i.e., learning and mastery) (Bandura & Schunk, 1981; Multon, Brown, & Lent, 1991). Furthermore, persistence and practice have been directly linked to increases in students' learning and mastery (Newell & Rosenbloom, 1981). It is important to note that, at times, previous research has treated the concept of engagement as both a motivational construct (Corbett & Anderson, 2001) and as a behaviour/mental state (Moreno & Mayer, 2005). For this reason, engagement spans Columns 3 and 4 within Figure 1. Overall, the concepts represented within Figure 1 have been examined within prior research with evidence suggesting that they should support an enjoyable (likely engaging) and productive learning environment that sustains students' interest (Young et al., 2012).

The Motivation and Mastery Cycle Framework

The complex interrelations between constructs related to motivation and learning led us to develop the *Motivation and Mastery Cycle* framework illustrated in Figure 2. We propose a cyclical framework that describes how these constructs are related, modify each other across time, and ultimately support positive learning outcomes. Our hope is that the combination of these constructs within a theoretical framework will provide promising insights into the potential long-term benefits from educational games.

This cycle consists of interrelated constructs that may contribute to at least a portion of the complex relations across time between game-based elements, motivation, and learning. The Motivation and Mastery Cycle framework includes empirically supported relations that connect: 1) interaction mechanisms to interest, enjoyment, and persistence, and, 2) persistence to mastery, 3) mastery to self-efficacy, and 4) self-efficacy back to interest/ enjoyment. The explicit links in this figure clearly do not represent all of the possible combinations of relations and factors that contribute to motivation and learning: they include only a subset of those relevant to this framework. For example, the previously mentioned constructs of engagement and flow are commonly researched concepts that relate to positive learning outcomes and could fit within the framework below as potential replacements for interest/enjoyment (Baños et al., 2004; Hannafin & Hooper, 1993; Singer & Witmer, 1999; Wirth et al., 2007; Reese, 2010). These constructs were omitted from Figure 2 in an attempt to keep the figure simple, straight forward, and to have each targeted link supported by strong empirical support (i.e., engagement is theoretically related to environment persistence, however, there are decades worth of research directly connecting user interest to activity persistence and thus it has a stronger empirical base and associated rationale for inclusion within this framework example).

The following sections briefly describe the rationale underlying assumptions 1 through 4 within the Motivation and Mastery Cycle depicted in Figure 2.

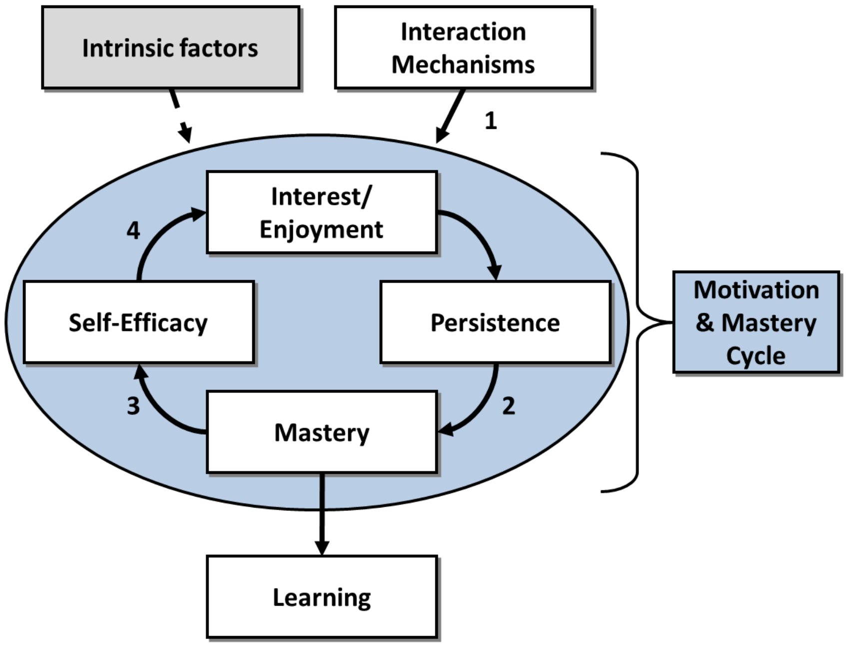

Figure 2. Motivation and mastery cycle framework.

Interaction mechanisms to interest, enjoyment, and persistence. A key assumption depicted underlying the Motivation and Mastery Cycle framework is that interaction mechanisms that are commonly used in games (i.e., listed in column 2 of Table 1, and the second column of Figure 1) impact interest and enjoyment, and in turn, persistence. Much of this research is described in McNamara et al., (2010). A good deal of research has supported the notion that game-based interaction mechanisms help to maintain interest and in turn increase persistence -- especially in the face of failure (Fisher & Ford, 1998; Graesser, Chipman, Leeming, & Biedenbach, 2009; Miller & Hom, 1990; Moreno & Mayer, 2005). *Interest* is related to to the degree to which learners' underlying needs or desires are energized (Alexander et al., 1997). *Individual interest* is often characterized by the desire to become more competent and increase expertise in a particular topic or domain. By contrast, *situational interest* is specific to particular events and contexts, and is thus transitory (Alexander et al., 1997; Hidi, 1990; Murphy & Alexander, 2000; Schiefele, 1991). For the latter, the way in which content is framed is crucial in driving interest. Importantly here, framing content within a game can be used to capture the interest of a fundamentally disinterested student. For example, incentives or performance-contingent rewards (e.g., points that can be traded for powers, tools, or weapons) can help to spike student interest and prolong engagement (Graesser, Chipman, Leeming, & Biedenbach, 2009; Moreno & Mayer, 2005).

Challenge, control, and fantasy are also potent game features that increase related factors such as students' interest, enjoyment, engagement, and overall motivation (Corbett & Anderson, 2001; Malone & Lepper, 1987; Shaffer, 2007). As discussed earlier, challenge, and in particular, the appropriate level of challenge, is often regarded as a critical feature of successful video games (e.g., Conati, 2002; Malone & Lepper, 1987; Prensky, 2005). Likewise, fantasy, which is often invoked by an immersive narrative, is often used in games to engage learners (Barab et al., 2009; 2010P). Control over the game environment, and a consequent sense of agency, is also a fundamental aspect of games, which in turn increases engagement (Snow, Jacovina, Allen, Dai, & McNamara, 2014; Snow, Allen, Jacovina, & McNamara, 2015).

Persistence to mastery. Research on skill acquisition and mastery has consistently demonstrated a strong link between the amount of practice (i.e., persistence) and the level of skill performance or mastery (Anderson, 1982; Ericsson, Krampe, & Tesch-Romer, 1993; Healy et al., 1993; Newell & Rosenbloom, 1981). Therefore, with greater amounts of practice, students will increase skill proficiency and develop mastery over time. This mastery process inherently includes learning of the targeted skill domain. Thus, learning is a by-product of this interaction over time (as long as the game tasks focus on the targeted skill).

Mastery to self-efficacy. Self-efficacy refers to an individual's sense of ability, potential success and achievement (Bandura, 2000; Pajares, 1996). When a person has a high level of self-efficacy regarding a task, this reflects the belief that the task can be successfully completed. Some researchers have argued that tutoring systems should attempt to build students' self efficacy, particularly when they are unsuccessful in the learning task (Lepper, Drake, & O'Donnell-Johnson, 1997; Lepper & Wolverton, 2002). An increase in mastery has a corresponding increase in self-efficacy for that skill. As students improve task proficiency (i.e., build mastery) they also tend to increase in their perceived competency or self-efficacy (Bandura & Schunk, 1981; Martens & Witt, 2004).

Self-efficacy back to interest/enjoyment. Finally, research has suggested that self-efficacy is positively related to interest and enjoyment (Bandura & Cervone, 1983; Pintrich & De Groot, 1990; Schunk, 1991; Zimmerman & Kitsantas, 1997). More specifically, students in a moderate range of self-efficacy tend to have higher levels of interest, while students on the extreme ends (both low and high) of self-efficacy tend to have lower interest, likely due to difficulty or boredom, respectively (Silvia, 2003). Further, self-efficacy influences how much effort learners will put forth and how long they will persist in order to succeed (Tipton & Worthington, 1984).

Intrinsic factors versus interaction mechanisms. The two inputs at the top of Figure 2 (intrinsic factors and interaction mechanisms) are expected to contribute differently to the motivation and mastery cycle for various students (i.e., some students will be intrinsically motivated to pursue activities on their own, while other students may need additional incentives to become involved). For students with a low prior ability and/or low initial interest, interactions with game-based features may be especially helpful to create initial interest and encourage persistence, which helps to improve mastery and increase self-efficacy. Thus, these interaction mechanisms may provide a sufficient hook to engage learners who might otherwise be disengaged from the target learning process. These mechanisms may provide an impetus to sustain these interactions for these disengaged users, in turn leading to increased persistence, mastery, and self-efficacy. Initial increases in self-efficacy for these low ability students should have a corresponding positive jump in interest and thus help to perpetuate the cycle and longer-term interactions with the educational system. In contrast, students with an existing intrinsic interest in the target domain (top-left box in Figure 2) will already have a high level of interest and are less likely to rely on the game-based aspects to remain persistent, gain mastery, and build self-efficacy; however they may also progress through the cycle and improve mastery, self-efficacy, and interest over time. Therefore, the motivation and mastery cycle describes the general relation between interest/enjoyment/engagement, persistence, mastery, and self-efficacy while acknowledging that multiple factors may contribute to an individual’s sustainment within that cycle.

In sum, the links between these motivational constructs support each other and suggest a potentially self-sustaining cycle of increasing motivation and mastery. In the context of computer-based learning environments in particular, incorporating game elements can be expected to prolong students’ persistence at the target task. While some game elements may be unnecessary, ineffective, or even distracting in the short-term, they have the potential to increase interest, enjoyment, and engagement in the long-term. Both intrinsic factors and interaction mechanisms can influence a student’s progress through the motivation and mastery cycle. However, many students, particularly low interest students, will likely rely on the game features and interaction mechanisms to sustain prolonged interactions; hence the potential benefit for motivating game-based environments.

Tentative Support

A combination of previous studies conducted by the authors provide some tentative support to the proposed frameworks presented here (Jackson, Dempsey, Graesser, & McNamara, 2011; Jackson, Dempsey, & McNamara, 2012; Jackson & McNamara, 2013). In Jackson et al., (2012) students participated in a relatively short 90-minute experiment and interacted with a traditional ITS, called iSTART (Interactive Strategy Training for Active Reading and Thinking), or a short educational game (covering the same material). iSTART is an ITS that provides young adolescent to college-aged students with comprehension strategy training to better understand challenging science texts. It does so by providing students with training and practice using self-explanation in conjunction with effective comprehension strategies such as generating bridging inferences and elaborations while reading (McNamara, O’Reilly, Best, & Ozuru, 2006). A game-based version of iSTART, called iSTART-ME (motivationally enhanced), was developed to increase students’ motivation and engagement while learning the comprehension strategies. The game-based environment affords opportunities to earn points, advance through levels, purchase in-game rewards, personalize a character, and play educational mini-games (designed to use the same strategies as in practice). Jackson et al., (2012) compared the effects of the iSTART coached practice to the game-based version, called Showdown, in iSTART-ME. In Showdown, participants compete against a computer player by attempting to write a higher quality self-explanation. Similar to the original coached practice in iSTART, participants read a text and generate a self-explanation for a target sentence. But, a crucial difference between Showdown and the ITS version of coached practice is the element of competition. Within Showdown, after the player submits a self-explanation, a computer-selected (competing) self-explanation is presented. The self-explanation scores (generated using a natural language processing algorithm) are compared and the player with the most stars wins the round and the player who wins the most rounds at the end of the game is declared the winner. Students found this game environment significantly more engaging than coached practice in iSTART; but the students who interacted with iSTART had higher performance (produced better explanations).

In a second study (Jackson et al., 2011), students interacted with a larger game-based environment across six separate sessions. This larger environment included both the traditional ITS and the game-based environment from the prior study (Jackson et al., 2012). In this second study, there were no performance differences between the ITS and the game-based system, but the game-based environment was still rated more favourably than the traditional ITS (albeit marginally significant). These findings suggest that the integration of game-based features and interaction mechanisms have an effect on motivation, but that they may also interact with learning and performance within the environments. One of the most interesting aspects of these studies are the differences in terms of time-scale effects on motivation and performance. Effects found from a limited, short-term interaction were very different from the results of a longer interaction with the same environments (although the second study was not a between-subjects study). These findings contributed to the conceptualization of the Motivation and Mastery Framework depicted in Figure 2 and prompted the authors to further investigate the timescale effects of learning and motivational constructs between a traditional ITS and a full game-based environment.

Jackson and McNamara (2013) further examined the effects of game-based learning environments across an eight session study where students interact with either iSTART to iSTART-ME. Students in both conditions received the same training on reading comprehension strategies. After receiving the initial training, participants (high school students) in the traditional ITS condition engaged with coached practice across a library of texts. These participants interacted with the same environment across all practice sessions and received pedagogical feedback through verbal and visual indications of self-explanation quality. In contrast, after completing the initial training, students in the game-based version of the system were taken to a game-based selection menu system where they could engage in the same generative self-explanation practice across environments with different surface-level game features. As a part of this practice, their performance contributed to a larger game-based system that provided elements of feedback (points, levels), incentives (points, personalized avatars, variety), task difficulty (challenge, competition), control (personalization, variety), and environment (personalization, game aesthetics). Thus, participants in both conditions received the same training, and engaged in the same cognitive skill practice (i.e., self-explanation), but only those in the game-based system received the additional features identified within Figure 1.

The results from a daily administered survey in Jackson and McNamara (2013) illustrated that students who interacted with the game-based system tended to improve their perception of the system over time, had improved self-efficacy (compared to students using the ITS), and slowly increased (or at least maintained) motivation for future interactions. In contrast, those students who interacted with the traditional tutoring system showed decreases in enjoyment, motivation, self-efficacy, and desire for future interactions. In addition to the daily survey results, analyses of pretest and posttest outcome measures revealed that performance (mastery) improved and was equivalent across the two conditions. Thus, even with the addition of game-based features, both systems produced equivalent improvements in learning and mastery.

From these findings, it appears that the game components present within the game-based version of the system seemed to be activating related constructs (similar to those from the framework) that remained effective and accumulated across time as suggested in Figure 2 (rather than a simple on or off effect). These trends were also fairly gradual, indicating that changes may have occurred in smaller increments and slowly built up with more iterative interactions (supporting the cyclical nature of the framework).

Students' persistence at the practice tasks was held constant across conditions in this study (all students completed the same number of training sessions), and thus that aspect of the cycle is not addressed in this study (i.e., there is no method to directly determine attrition likelihood for either environment). However, the significantly different levels of self-efficacy and enjoyment are not constrained by time and can likely be attributed to the selected system features and interaction mechanisms that were employed by each system. Thus the significant differences in terms of self-efficacy, enjoyment, and motivation tend to support the second half of the motivation and mastery cycle (self-efficacy and interest/enjoyment).

It is also worth noting that the minimal game-like features already implemented within the traditional iSTART ITS system (i.e., verbal and visual feedback, animated character, points) were not enough to produce the same motivational improvements as the fully game-based version of training. This finding is potentially significant for system developers because just adding in a few game-like features is probably not enough to produce the effects found in more coherent and contextually bound educational games.

To achieve the desired potential for educational games, these systems must be designed to foster significant increases in learning, but they must also be enjoyable and engaging to use. In the case of long-term skill-based tutors, these systems must not only teach the strategies themselves, but also provide an effective, motivating practice environment where students can apply this training and sufficiently develop the target skills into more automatic and stable processes.

CONCLUSION

Educational games are uniquely situated to enable the complementary synergy between sophisticated pedagogical systems and engaging game environments. The designs and development of these systems go beyond isolated effects stemming from separate technologies (e.g., adding arbitrary points to an existing task) and embody complex interaction mechanisms supported by foundational research (integrating points as a form of performance feedback, a method for incentives, and an indicator of task difficulty). These interaction mechanisms (e.g., feedback, control) contribute unique affordances to the system design and have the potential to impact a variety of constructs that promote sustained engagement, learning, and mastery.

A compilation of prior research provide an initial sketch of the landscape for design features (Figure 1) and suggest how individual or combinations of features may theoretically contribute to changes in motivational and learning constructs. Within Figure 1, each relation depicted by an arrow represents empirical findings from related work (e.g., education, psychology, computer science, game design). However, the full paths of Figure 1, including the downstream effects from the first column through the last column, have not yet been empirically tested. This chapter includes an illustration of these theoretical connections and provides an applicable framework to facilitate design decisions for future system development.

Likewise, Figure 2 depicts a potential explanatory framework that supports the design and development of long-term game-based educational systems to promote motivation and mastery. Utilizing the landscape of constructs within Figure 1, reinforcing connections were discovered across related research efforts, resulting in a cyclical, relational framework between motivational and learning constructs. The motivation and mastery cycle in Figure 2 visually illustrates these relations and outlines some of the theoretical value possible with long-term game-based educational environments (i.e., how game mechanisms feed into the cycle to promote persistence and mastery). Prior work conducted by the current authors provides some tentative support for the frameworks presented here. Namely, positive motivational effects were found for a game-based system, these effects accumulated over time (supporting the cyclical nature), and corresponded to similar increases among the framework constructs (enjoyment, mastery, and self-efficacy; with persistence being held constant).

Future work is needed in this area to further develop the landscape of game-based features, how they are used (interaction mechanisms), and what downstream effects are produced (motivation constructs, mental states, and learning). Leveraging and extending this work will help designers and developers better understand the complex relations and implications of initial system design decisions, real-time effects, and subsequent outcomes. Establishing these relations would facilitate and advance the ability to design and implement more engaging and effective environments that promote content mastery, positive affect, and task persistence.

Although the current work does not represent an exhaustive list of related research within educational games, it does focus on the empirically supported and theoretical potential of educational games along with support for how these environments can be designed to be more effective and engaging. The previous research discussed here supports the advancement of educational games, describes how environment features can be potentially used to afford system designs that combine effective pedagogy with motivating interactions, and provides two tentative frameworks to help guide system design and explain potential outcomes and benefits.

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