Applying Motivation Theory to the Design of Game-Based Learning Environments

Jon R. Star, Jason Chen, and Chris Dede

Abstract Although there has been a wealth of research exploring motivation within game-based learning environments, few of these studies employ frameworks that are grounded in well-established theories of motivation. This chapter brings a rigorous theoretical framework for motivation to the study and design of a game-based learning environment. First, we outline a key motivation construct that has potential value for the design of game-based learning environments—Eccles and Wigfield's expectancy-value theory. We then provide a description of a game whose design was informed by this motivational theory, where the game was intended to promote students' interest in and motivation to pursue science, technology, engineering, and mathematics (STEM) careers.

Keywords Expectancy-value theory • Motivation • Game-based learning environment • STEM

Though much effort has been put toward integrating game elements in educational spaces to improve learning, results have been disappointing (Hogle, 1996; Kerawalla & Crook, 2005). One reason for this unsuccessful hybrid is that designers have taken a "chocolate-covered broccoli" (Bruckman, 1999) approach in which the gaming element is a reward for completing the educational component. Game-based learning environments need to be designed in a way that allows for the learning material to be delivered through the parts of the game that are most motivating (Habgood, Ainsworth, & Benford, 2005). The purpose of this chapter is to bring rigorous theoretical frameworks of motivation to the study and design of game-based learning environments. Although there has been a wealth of research exploring motivation within game-based learning environments, few of these studies employ frameworks that are grounded in well-established theories of motivation (Moos & Marroquin,

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2010). In this chapter, we first introduce a prominent theory of motivation that can be applied to the design of game-based learning environments—expectancy-value theory. Second, we illustrate how this motivational theory was drawn upon in the design of a game designed to promote students' interest in and motivation to pursue science, technology, engineering, and mathematics (STEM) careers.

Theories of motivation can offer researchers, educators, and designers useful and theoretically grounded constructs that can be empirically applied and studied in educational contexts. By motivation, we are referring to the "the process whereby goal-directed activity is instigated and sustained" (Pintrich & Schunk, 2002, p. 5). Increasing student motivation is a prime target for improving education because what people believe is quite often a better predictor of actual performance than is previous achievement or even actual capability (Bandura, 1997). In this light, it is quite disheartening for teachers, for example, to see a student who exhibits great potential, but because of self-doubt or lack of interest in a subject, does not perform on par with what that student should be able to do. Some scholars argue that motivational factors play a larger role than academic performance in predicting continued learning. For instance, in an introductory undergraduate psychology course during freshman year, motivation was more predictive of subsequent course taking and majoring in psychology over a 7-year span than were grades from that introductory course (Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002). Similar patterns have been found for middle school and high school students (Harackiewicz et al., 2002; Hidi, 1990; Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006). Though research on motivational theories and their applications to education has generated thousands of journal articles, there is relatively little empirical evidence about whether these theories also hold up in game-based learning environments.

Expectancy-Value Theory

One widely used theory of motivation in education research is Eccles and Wigfield's expectancy-value theory (e.g., Eccles, 1987, 1993; Eccles et al., 1983, 1989; Wigfield, 1994; Wigfield & Eccles, 1992, 2000). As its name implies, expectancy-value theory proposes that students' motivation to engage in an activity is influenced by two factors—the degree that students believe that they expect to succeed in the activity, and the degree that students value participation in the task. This theory provides a useful framework for understanding students' beliefs about how competent they are and what they value within the context of their academic studies.

With regard to expectancy, students are motivated toward or away from particular activities by answering the question, "Can I do this?" This question refers to students' belief in their own competence, also known as self-efficacy. Decades of research have shown that students' self-efficacy, defined by Bandura (1997) as "the belief in one's capabilities to organize and execute courses of action required to produce given attainments" (p. 3), is a powerful influence on motivation and achievement. Bandura (1997) hypothesized several sources of self-efficacy, including *mastery experience* (the interpreted results of one's past performance), *vicarious experience* (observations of others' activities, particularly individuals perceived as similar to oneself), and *physiological and affective states* (anxiety, stress, and fatigue)—each of which has been linked to performance in math and science, including students' persistence in STEM fields and choice of STEM majors (e.g., Britner & Pajares, 2001; Gwilliam & Betz, 2001; Lau & Roeser, 2002; Lent, Brown, & Larkin, 1984). Furthermore, teachers with higher self-efficacy plan lessons better demonstrate higher levels of organizational skills, and put in more effort in helping struggling learners than do their peers who have lower self-efficacy (Allinder, 1994; Ashton & Webb, 1986; Gibson & Dembo, 1984).

The second component of expectancy-value theory is value. To be motivated to do something, students must not only believe that they have the competence to do it, but they also need to see the value of doing it. For instance, students can easily decide that they are highly capable at succeeding in math; but, if they do not see the point of becoming proficient, there is no reason for them to exert the necessary effort to succeed. The construct of value is considered to have four components: The perceived importance of the task based on it being enjoyable and fun to engage in (interest), influential to the individual's identity (attainment), useful in the individual's life (utility), and having perceived negative aspects of engaging in the activity, such as negative emotional states (cost). Studies have indicated that task values (particularly interest and utility) are associated with course enrollment decisions, free-time activities, and intentions (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002).

In sum, the expectancy-value framework of motivation posits that individuals will be motivated to engage in a task to the extent that they feel they can be successful at it and to the extent they perceive the task as being important to them.

Application of Expectancy-Value Theory to the Design of a Game-Based Learning Environment

A project at Harvard's Graduate School of Education, entitled Transforming the Engagement of Students in Learning Algebra (TESLA), illustrates how a theory of motivation (in particular, expectancy-value theory) can be incorporated into game-based learning environments. For this project, the researchers created a 4-day mathematics intervention, 2 days of which involve one of several game-based learning environments for students in Grades 5–8 before classroom instruction. In this chapter, we describe one of the game-based learning environments that was specifically designed to increase students' motivation for STEM by aligning with expectancy-value theory. This game was an Immersive Virtual Environment (IVE) that was designed to introduce students to the mathematical concepts that were to follow in a subsequent lesson. The IVE was professionally produced such that it was similar in look and feel to video games that students may have had experience playing.

Fig. 1 Opening screen, space rescue mission

Game description. Prior to beginning the IVE, each student viewed a short (5-min) video clip of a young STEM professional who talked about the nature of the work they do (e.g., designing astronaut space suits), the difficulties they had encountered in their K-12 math and science classes, and how they were able to overcome these difficulties. Students were provided with a selection of several of these videos, which varied according to the demographic attributes of the STEM professionals (e.g., gender, ethnicity); students were allowed to select whichever single video they wanted to view before beginning the IVE.

For the story line of the IVE, students were provided with the opportunity to explore an outer space environment in the context of a space rescue mission (see Fig. 1). A total of five mathematical puzzles were encountered as students moved around the planet; all puzzles related to the generation of and identification of mathematical patterns, similar to what would subsequently be discussed in a mathematics lesson. The first puzzle allows students to become accustomed to how to function and interact in the virtual world and is similar to a combination-lock problem in that students must identify all possible ways that three numbers can be combined to produce a unique 3-digit number (see Fig. 2). When students finish, they proceed to a more complex and difficult second puzzle.

In the second puzzle, students encounter a door that is locked (see Fig. 3). Next to the door is a box with complex circuitry. Parts of this circuit board are complete, but the great majority of it is broken. Students must “fix” each section of the circuit board by building circuits with 1- and 2-unit length fuses. The circuits that must be constructed differ in size—at first, students build a 1-unit long circuit (only one

Fig. 2 First puzzle, combination-lock problem

Fig. 3 Second puzzle, Fibonacci circuit problem

possible combination if presented with only 1- and 2-unit long fuses). Then, they build circuits that are 2-unit long (2 possibilities: 1 + 1 and 2), 3-unit long (3 possibilities: 1 + 1 + 1; 2 + 1; and 1 + 2), and so forth, until they reach a circuit that is 9-unit in length (55 possible combinations) (see Fig. 3). What emerges from this activity is the fact that a Fibonacci series, in which each subsequent number of possible combinations is the sum of the previous two, underlies the pattern (1, 2, 3, 5, 8, 13, 21, 34, 55). Because students are not explicitly taught the Fibonacci series in school, most students are likely to enter this activity unaware of this pattern. However, due to its simplicity, the activity is well within students' cognitive abilities.

Beyond the second puzzle, the game included three more puzzles that were increasingly difficult but mathematically related to the first two puzzles—in that these later puzzles also focused on mathematical patterns and the Fibonacci series. Upon completion of the final puzzle, the game concludes as a final door opens and the player is able to rescue the ship's captain.

Design elements focusing on expectancy. In creating a game that is motivationally sound and that draws upon expectancy-value theory, we made a number of purposeful design choices. To begin, consider the following design elements intended to foster the growth of expectancy for success (self-efficacy). First, we removed common elements of many commercial games that the motivational literature suggests may undermine or distract students from the learning and motivational goals, including competition, time-sensitive pressures, and overt performance goals. As a result, the IVE did not include a timer or clock, did not focus on the accumulation of points or levels, and did not place players in competition with one another. Second, the IVE began with a relatively easy first puzzle so that students could familiarize themselves with the controls as well as experience early success. This type of initial success in the game was intended to build students' self-efficacy for solving these types of problems as they began playing the game.

Third, the later puzzles in the game are designed with a complex progression of scaffolds and hints, which are included and removed purposely to promote the growth of self-efficacy. In particular, consider the scaffolds that are in place in the second puzzle, which is considerably more complex than the first puzzle and is designed to be quite challenging for students. If students were given the entire second puzzle all at once, many could be overwhelmed and quickly become discouraged. Instead, we designed this activity with supports and hints that are progressively removed so that students can develop a belief that they are able to solve this type of problem, which is directly related to expectancy. For example, students start out by building actual circuits that are 1-unit, 2-unit, and 3-unit in length using only 1-unit and 2-unit long fuses before tackling longer circuits that require pattern recognition. Through these mastery experiences, students' perceived past successes lead them to become more confident in being able to accomplish similar tasks. According to Bandura (1997), mastery experiences are the most powerful source of self-efficacy, which makes it an attractive way to build expectancy for success in this virtual environment.

Furthermore, when students reach circuits that are 4- and 5-unit long, the number of circuits that can be built at each height increases dramatically. Building each individual circuit becomes not only more difficult, but also more tedious. Therefore, students are shown all the different combinations that can be built at 3-unit high (e.g., $1+1+1$; $2+1$; and $1+2$ for a total of three circuits) and 4-unit high. From this information, they must make an educated guess as to how many circuits can be made, using 1- and 2-unit length fuses, when the circuit is 5-unit in length. Students are no longer building this circuit from scratch (removing a scaffold) but are instead deducing patterns. If they guess incorrectly, feedback is provided to students so that they can begin to build the individual circuits in a systematic and orderly fashion.

As students progress through this step to more complicated circuits (6-, 7-, 8-, and 9-unit high), more scaffolds are removed so that students are progressively given more autonomy and responsibility for providing the correct response. Again, appropriate feedback is provided every time a student does not generate the correct response. At the end (for the 9-unit long circuit that requires 55 unique combinations), the environment is constructed so that students are not given the opportunity to build the circuits if their initial estimate is incorrect. Rather, students are given a visual cue showing the entire series of circuits that has been constructed, highlighting how many circuits were built at each length (1, 2, 3, 5, 8, etc.); students are then asked if they can identify a pattern from these numbers.

Together, this rather complex series of scaffolds (which we describe for the second puzzle but which are also present in the third, fourth, and fifth puzzles) are designed to help students come to the realization that they can in fact solve what appears to be complex problems—to provide them with mastery experiences to bolster their expectancy for success.

Design elements focusing on value. In addition to fostering expectancy, the game also includes elements designed to bolster value. In particular, students are introduced to eight real-life STEM professionals before attempting to solve the five puzzles. Students choose one of these STEM professionals to be the "team lead" for the puzzle-solving mission. They then watch a short video that introduces them to the STEM professional. In this video, students are able to find out answers to questions such as, "Why is your job so awesome?" and "What obstacles have you faced in your path to becoming a STEM professional and how did you overcome them?" Because the models in the interview are young, are in careers that students are apt to view as attractive (e.g., space suit designer for NASA), and are ethnically diverse, we hope that students can readily identify with the role model to whom they are matched and can reap the motivational benefits more easily than if the models were perceived as completely dissimilar to the students. These videos address the value component of the expectancy-value theory by illustrating the relevance of algebra knowledge (utility construct) and presenting careers that may be appealing to some students to increase motivation to pursue STEM careers (interest construct).

Conclusion

It is clear that, for learning to be optimal, students must be motivated. The theoretical framework addressed here provides rigorously studied and theoretically grounded constructs with which researchers and designers can study and create game-based learning environments that enhance the experience of learning. We have provided one example of how a theory of motivation can be applied to the design of a game-based learning environment, but there are a great many other ways that these theories can be applied. Even more exciting is the fact that game-based learning environments can be designed in ways that can allow researchers to test many different experimental variations, providing researchers and designers with empirical evidence for which design decisions may be appropriate for whom under what conditions. We encourage researchers to conduct these types of micro-level analyses, which can provide useful information on designing motivationally optimal game-based learning environments.

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