Articles

2012

Applying Motivation Theories to the Design of Educational Technology

Cathy Tran
University of California, Irvine

Jason Chen
College of William & Mary, jachen@email.wm.edu

Mark Warschauer
University of California, Irvine

AnneMarie Conley
University of California, Irvine

Chris Dede
Harvard University

Recommended Citation

Applying Motivation Theories to the
Design of Educational Technology

Cathy Tran, University of California, Irvine, ctran27@gmail.com
Jason Chen, Harvard University, jchen04@gmail.com
Mark Warschauer, University of California, Irvine, markw@uci.edu
AnneMarie Conley, University of California, Irvine, ampm@uci.edu
Chris Dede, Harvard University, chris_dede@gse.harvard.edu

Abstract: Although there has been a wealth of research exploring motivation within technological environments, few of these studies employ frameworks that are grounded in well-established theories of motivation. This paper brings rigorous theoretical frameworks of motivation to the study and design of educational technology. First, we outline key motivation constructs that compose Eccles and Wigfield's Expectancy-Value theory and the Self-Determination theory and discuss their implications for education. Through a case study, we then illustrate how motivational theories informed the recent development of a virtual learning environment designed to promote students' interest in and motivation to pursue science, technology, engineering, and mathematics careers. Finally, looking toward the future of mobile learning, we discuss the motivational affordances of personal and portable features of mobile handhelds.

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. Educational games 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 paper is to bring rigorous theoretical frameworks of motivation to the study and design of technology-based learning environments. Although there has been a wealth of research exploring motivation within technological environments, few of these studies employ frameworks that are grounded in well-established theories of motivation (Moos & Marroquin, 2010). In this paper, we first introduce two theories of motivation that can be applied to the design of educational technology. Second, we illustrate how motivational theories informed the development of a virtual learning environment designed to promote students' interest in and motivation to pursue science, technology, engineering, and mathematics careers. Third, we look toward the future of mobile learning and discuss the motivational affordances of personal and portable features of mobile handhelds.

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 et al., 2002). Similar patterns have been found for middle school and high school students (Hidi & Harackiewicz, 2000; Hidi, 1990; Hidi & Renninger, 2006; Harackiewicz et al., 2002). 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 educational technology settings.

Motivation Theories
We highlight two theories of motivation that offer researchers, educators, and designers useful and theoretically grounded constructs that can be empirically 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). Both the Expectancy-Value theory and Self-Determination theory highlight what influences this goal-oriented process.

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, Adler, et al., 1983; Eccles, Wigfield, et al., 1989; Wigfield, 1994; Wigfield & Eccles, 1992, 2000). 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. Students are motivated toward or away from particular activities by answering the question, "can I do this?" This question lies at the heart of the *expectancy* component of theory. Furthermore, 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. Task values are defined by 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). 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.

Self-Determination Theory

The Self-Determination Theory suggests that motivation arises from the needs for competence, autonomy, and relatedness being met (Deci & Ryan, 2000). That is, to be motivated, people need to feel that they are the following: (1) capable of understanding the material; (2) in control of their environment; and (3) socially connected in the process. Research shows that these three needs contribute to inherently enjoyable activities that are therefore intrinsically motivating. Compared with those pursuing an activity for external rewards such as money or grades, intrinsically motivated individuals are more creative, enjoy the activity more, and process information more carefully and completely (Ryan & Deci, 2000). Our premise is that by using technology to address the psychological needs of competence, autonomy, and relatedness, we can foster sustained engagement and positive learning outcomes.

Application of Expectancy-Value Theory to a Virtual Environment

An NSF-funded project at Harvard's Graduate School of Education, entitled *Transforming the Engagement of Students in Learning Algebra* (TESLA), illustrates how motivation theories can be incorporated into instructional technologies. For this project the researchers created a 4-day mathematics intervention, two days of which involve one of several technology-based motivational inductions for students in Grades 5-8 before classroom instruction. In this paper, we highlight one condition in which the game-like activity introduces students to math concepts through their avatars' active involvement in an event. In designing an environment that is motivationally sound, we removed elements of commercial games that either undermine or distract from the learning and motivational goals (e.g., competition, time-sensitive pressures, and overt performance goals).

292

Figure 1: **Opening screen: Space rescue mission**

Students solve a total of five puzzles in the game, recognizing mathematical patterns in the context of a space rescue mission (see Figure 1). The first puzzle allows students to become accustomed to how to function and interact in the virtual world. As such, the mathematical puzzle is relatively easy so that students can familiarize themselves with the controls as well as experience early success to build their self-efficacy for solving these types of problems. Self-efficacy, defined as one's confidence in accomplishing a particular task, is closely associated with the expectancy construct of the Expectancy-Value theory (Bandura, 1997). This first puzzle 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 Figure 2). When students finish, they proceed to a more complex and difficult second puzzle. This puzzle is broken down into smaller steps to scaffold students' learning and thereby increase their self-efficacy to solve a complex problem. If students were given the entire puzzle all at once, many could be overwhelmed and quickly become discouraged.

Figure 2: **First puzzle: Combination-lock problem**

For the second puzzle, students encounter a door that is locked. 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 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 Figure 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.

We designed this activity with many cognitive scaffolds in the beginning that are progressively removed so that students can develop a belief that they are able to solve this type of problem (i.e., 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.

Figure 3: **Second puzzle: Fibonacci circuit problem**

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 3 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.

Therefore, what we are doing is scaffolding the capability to recognize algebraic patterns (the Fibonacci series in this case). Our hope is that, after finishing this activity, students will be able to recognize one type of algebraic pattern and be able to apply that same type of thinking to the types of patterns that they will be facing in their future math lessons. Ultimately, this type of scaffolding is designed to help students come to the realization that they can in fact solve what appears to be complex problems—provide them with mastery experiences to bolster students' expectancy for success.

To address the value component of the Expectancy-Value theory, 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).

We hope that, by providing a case study of this NSF-funded project underway at the Harvard Graduate School of Education, we could illustrate heuristics for how motivation theory can inform the design of educational games and other technology.

Application of Self-Determination Theory to Mobile Learning

For the growing field of mobile learning, we believe that there is promising untapped potential when it comes to applying motivation theories to the design of those environments. Part of this optimism stems from looking at the growing literature on how mobile games—and games in general—motivate goal-directed behavior (Gee, 2003; Przybylski et al., 2010). Every day, for instance, players of *Angry Birds* invest 300 million hours in launching birds at towers of bricks and rocks in an effort to destroy pigs (Rovio, 2011) and more than 30 million harvest their crops in the social network game *Farmville* (Cashmore, 2010). When people are asked why they sacrifice other leisure, and perhaps non-leisure, activities to engage in such games, the immediate and most obvious response is simply because they are fun. Motivation can be thought of as being synonymous with the fun that is experienced in games; as such, unpacking what makes games fun can help us in designing educational technology that foster highly motivated learners.

In discussing mobile learning and motivation, we take the perspective of the Self-Determination theory, which posits that motivation arises from the needs for competence, autonomy, and relatedness being met (Deci & Ryan, 2000). We found this perspective to be most appropriate for this discussion for a couple reasons. Research shows that these three needs contribute to inherently enjoyable activities that are therefore intrinsically motivating (Ryan, Rigby, & Przybylski, 2006). This concept of intrinsic motivation is most closely related to what people mean when they say fun. Compared with those pursuing an activity for external rewards such as money, intrinsically motivated individuals are more creative, enjoy the activity more, and process information more carefully and completely (Ryan & Deci, 2000). Furthermore, the portable and personal nature of mobile technology is well suited to address the tenets of the Self-Determination theory of motivation as it already naturally allows for social connectedness (relatedness) and user control (autonomy). These two motivational elements are not addressed in the Expectancy-Value theory but still have important learning implications, especially in the free-choice environments that mobile handhelds are typically used.

Mobile handhelds are portable and personal, encompassing features that are especially applicable to the design of motivating learning environments. Handheld mobile technology has taken portability to a new level as cell phones have allowed for the digitally-tethered life, 24 hours a day, 7 days a week. This constant access frees the constraint of only being able to access data at a certain place such as a desktop computer or a library. Features such as location awareness takes advantage of this portable nature by embedding geotags to alert users of potential details of interest in their

geographical vicinity. Personal and intimate features of mobile handhelds stem from recent developments in tactile features and voice commands. Handhelds are now more responsive to human input as touchscreens react to pressure, motion, and the number of fingers used in touching the devices. Some devices react to shaking, rotating, tilting, or moving the device in space. Voice recognition and responses are becoming more sophisticated and are default features of newer smartphones. These portable and personal features can affect motivation for learning by functioning as new tools that designers can use in enriching learning environments.

One way that mobile handhelds can be used to increase motivation is by enhancing authentic learning. While desktop computers helped contextualize learning by bringing real-world context into the screen, mobile learning, on another level, has allowed for bringing the screen into the context. The Museum of London, for example, offers an iPhone app that allow users to view information and historical images overlaid on modern sites as they travel throughout the city (Johnson, Smith, Willis, Levine, & Haywood, 2011). Similarly, a project dubbed iTacitus (an acronym for "intelligent tourism and cultural information through ubiquitous services") gives users access to a visual time machine as they visit historical locations, such as the Coliseum, pan with their mobile device, and witness an event from the past (Johnson et al., 2011). These learning opportunities can target environments that people choose to engage in, allowing for an increased sense of autonomy. Another advantage of mobile handhelds is that the benefits of face-to-face communication can be paired with the cognitive scaffolds that technological devices afford. The technology-based cognitive scaffolds, such as performance feedback, address the need for competence whereas face-to-face interactions (e.g., augmented reality group activities) address the need for relatedness.

Furthermore, tactile features of mobile devices allow for tangible technology designs that increase motivation. For example, the multipoint touch-sensitive iPad display can be pinched to zoom in or out on an image and can detect when it is being moved or tilted. Such technology may offer unique benefits by allowing children to manipulate objects on the handheld while benefitting from the advantages of technology. For example, the game can support problem solving by introducing a delay after each action to encourage reflection. Or the game can be designed to foster particular strategies by changing the relative ease of moving objects in particular ways. Manches, O'Malley, and Benford (2010) demonstrated how constraining actions using a digital interface such that children could only move one object at a time resulted in the use of more efficient strategies in solving a math problem compared to using physical, non-technological representations. While it is possible to constrain actions using physical devices, it is typically more difficult to design ways to vary such constraints. Mobile handhelds allow for design affordances such as these to scaffold learning, addressing the motivational need for competence.

Conclusion

It is clear that, for learning to be optimal, students must be motivated. The two theoretical frameworks addressed here provide rigorously studied and theoretically grounded constructs with which researchers and designers can study and create technology-rich activities that enhance the experience of learning. Although we have provided examples of how theories of motivation can be applied to the design of technology activities, there are a great many ways that these theories can be applied. Even more exciting is the fact that technologies 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 environments.

References

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.
Bruckman, A. (1999). Can educational be fun? Paper presented at the Game Developers Conference '99, San Jose, CA.
Cashmore, P. (2010, February 20). Farmville surpasses 80 million users. Retrieved from http://mashable.com/2010/02/20/farmville-80-million-users/

Eccles, J. S., (1987). Gender roles and women's achievement-related decisions. *Psychology of Women Quarterly, 11*, 135-172.

Eccles, J. S., (1993). School and family effects on the ontogeny of children's interests, self-perceptions, and activity choice. In J. Jacobs (Ed.), *Nebraska Symposium on Motivation, 1992: Developmental perspectives on motivation* (pp. 145-208). Lincoln: University of Nebraska Press.

Eccles (Parsons), J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed), *Achievement and achievement motivation* (pp. 75-146). San Francisco: W. H. Freeman.

Eccles, J., Wigfield, A., Flanagan, C., Miller, C., Reuman, D., & Yee, D. (1989). Self-concepts, domain values, and self-esteem: Relations and changes at early adolescence. *Journal of Personality, 57*, 283-310.

Johnson, L., Smith, R., Willis, H., Levine, A., and Haywood, K., (2011). *The 2011 Horizon Report*. Austin, Texas: The New Media Consortium. Retrieved from http://net.educause.edu/ir/library/pdf/HR2011.pdf

Habgood, M. P. J., Ainsworth, S., & Benford, S. (2005). Endogenous fantasy and learning in digital games. *Simulation and Gaming, 36*(4).

Hogle, J. G. (1996). Considering games as cognitive tools: In search of effective "edutainment". Retrieved from http://www.twinpinefarm.com/pdfs/games.pdf

Kerawalla, L., & Crook, C. (2005). From promises to practices: The fate of educational software in the home*. Technology, Pedagogy and Education, 14*(1), 107-125.

Harackiewicz, J., Barron, K., Pintrich, P.R., Elliot, A., & Thrash, T. (2002). Revision of goal theory: Necessary and illuminating. *Journal of Educational Psychology, 94,* 638-645.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*, 549–571.

Hidi, S., & Harackiewicz, J. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of Educational Research, 70*, 151–179.

Hidi, S. & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41* (2), 111-127.

Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in children's self-competence and values: Gender and domain differences across grades one through twelve. *Child Development, 73,* 509-527.

Manches, A., O'Malley, C., & Benford, S. (2010). The role of physical representations in solving number problems: A comparison of young children's use of physical and virtual materials. *Computers & Education*, *54*(3), 622–640.

Moos, D. C., & Marroquin, E. (2010). Multimedia, hypermedia, and hypertext: Motivation considered and reconsidered. *Computers in Human Behavior, 26*, 265-276.

Pintrich, P. R. & Schunk, D. H. (2002) *Motivation in education: Theory, research, and application*. New Jersey: Merrill Prentice Hall.

Rovio. (2011, November 2). Angry bird mashes half a billion downloads. Retrieved from http://www.rovio.com/en/news/blog/95/angry-birds-smashes-half-a-billion-downloads

Ryan, R., & Deci, E. (2000). Self-determination and the facilitation of intrinsic motivation, social development, and well being. *American Psychologist, 55*, 68-78.

Ryan, R. M., Rigby, C. S., & Przybylski, A. K. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 30,* 347–364.

Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review, 6*, 49-78.

Wigfield, A., & Eccles, J. (1992). The development of achievement task values: A theoretical analysis. *Developmental Review, 12*, 265-310.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of motivation. *Contemporary Educational Psychology, 25*, 68-81.