Risk as a Gamification Element in Online Homework

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Abstract

Recent years have seen a great interest in gamification, whereby game-based elements, including as leaderboards, storylines, and badges, are added to educational activities in order to engage and motivate learners. In this paper, we contrast the main education game-design elements with elements found in other successful game formats, and we argue that some key elements of popular games – most notably, risk – are missing from educational gamification. We present some results from a study in which risk was incorporated into online homework in a post-secondary mathematics course and in which it was found that risk *can* be a successful element of gamification that serves to motivate and engage students.

Keywords: Gamification, game-based learning, online homework, math education
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Introduction

One way children learn is by playing games. Even adolescents and adults find games to be stimulating and engaging. It appears, therefore, that we have an innate disposition towards games. It is for this reason that educational scholars have long been intrigued with the prospect of harnessing that disposition and directing game-playing energies to achieve learning.

Recently, computer-based games for learning have been gaining ground in areas such as business, marketing and lifestyle modification. Some automobile GPS units, for example, have built-in games that reinforce more eco-friendly driving practices. But in education, game-based learning is just emerging [2]. There have been over a thousand papers published in the area of game-based learning, and recently a number of review articles, especially in the area of gamification, as opposed to full-fledged games (see [2]. [6], and [8]).

The literature contains several examples of the development of full-fledged games in which individuals play a video game that, among other things, attempts to teach something. The *Oregon Trail*, for example, is an adventure game in which players learn facts about the *Oregon Trail* along the way ([3], [5]).

The development of such full-fledged games to facilitate learning in post-secondary education, however, can be prohibitively expensive and time-consuming. Moreover, for

students, these games can be very inefficient, with little knowledge transference relative to the time involved. And these games may only be effective for a limited set of learning objectives.

An intriguing alternative to the development and use of full-fledged games is the concept of gamification – essentially, the addition of game-based elements to educational content to improve student motivation and engagement. [2].

Elements of Gamification

Nah et al. [6] reviewed the literature on gamification and found the following design elements for gamification have been discussed:

- prizes, rewards, points, badges, levels, leaderboards
- immediate feedback, progress bars
- peer interaction and collaboration
- storytelling
- avatar, character upgrades, customization, unlockable content

Conspicuously absent from this list is any notion of "risk" – an element of most games, where the fortunes of the player ebb and flow. In the popular game *Tetris*, for example, users must quickly solve a tile-matching puzzle with falling blocks before they are overwhelmed by them. *Tetris* lacks most of the above gamification elements, yet many players find it highly engaging, if not addictive, largely due to constantly being in a state of peril.

Let us consider the special case of gamification in mathematics courses at the post-secondary level. In mathematics, online homework typically takes places using one of a number of interactive learning systems, such as *WebWork*, *WIMS*, and *IMathAS* (see [1]). A literature search found only one paper (see [3]) that made a concerted effort to extend interactive learning environments for gamification. However, the game-design methods studied in that paper ([3]) were limited to badges and levels.

In this paper, we consider the potential of interactive learning environments for mathematical gamification.

Interactive Learning in Mathematics

Quantitative disciplines appear to have two advantages for developing interactive learning environments. First, quantitative questions are relatively easy to generate using templates. For example, consider the type of functions encountered in first year calculus. By selecting different numbers for the parameters in a single template function, a very wide range of functions could be represented. For example, the template

$$\frac{(a_1x^{b_1}+a_2x^{b_2}+a_3x^{b_3})^{c_1}}{(a_4x^{b_4}+a_5x^{b_5}+a_6x^{b_6})^{c_2}}d^{a_7x^{b_7}+a_8x^{b_8}+a_9x^{b_9}}$$

could be used to generate the following seemingly quite different functions:

$$(i)\ \sqrt{x^2+2x+1} \qquad (ii)\ \frac{2^x}{\sqrt{x^2+1}} \qquad (iii)\ x^3e^{x^2+1} \qquad (iv)\ \frac{x^3+2x}{x^4+1}$$

In theory, by randomly populating the parameters of a very small number of templates, students could be provided with an infinite number of unique practice problems that represent any question that they would encounter in the course. For example, the student could be asked to find the derivative of the above functions.

Second, through the aid of a computer algebra system, student input could be assessed for correctness. Even full solutions could be generated through templates, thus providing immediate feedback to a student.

This ability of interactive mathematical environments to generate and grade an unlimited number of questions has potential for gamification, for it easily allows for students to keep practicing unique questions until they meet their desired level of achievement. The question then becomes: how could we keep students motivated to continue using the system until their desired level of achievement is reached?

In the future, software could be structured to subtly encourage students to adjust their goals upwards as they achieve their desired results, so that their goals might, in many cases, become more ambitious over time. For instance, once a basic assignment is completed, bonus bonus marks could be made available to students who are willing to practice still more to achieve the level of correctly answering more challenging questions. In this way, software could be more useful for channelling and encouraging persistence in the face of challenging or daunting questions than could textbook practice questions and assignments alone.

Motivating and Engaging Users with Risk

In [7], the use of the interactive mathematical environment *Xero* for online homework problem sets in a second-year discrete mathematics course was studied (see Figure 1). What made the study unique was the fact that the problem sets were highly randomized. Assignment questions were generated from randomly selecting templates from a large pool, with each template generating a highly varied set of questions. Students were allowed an unlimited number of attempts at the assignment, with full solutions presented after each question was answered. While it is not uncommon to allow multiple attempts on online assignment questions in mathematics, these *Xero* assignments required students to redo the entire assignment instead of individual questions to improve their score. However, due to the

high degree of randomization, each attempt would require a student to complete an assignment comprised of a completely different set of questions.

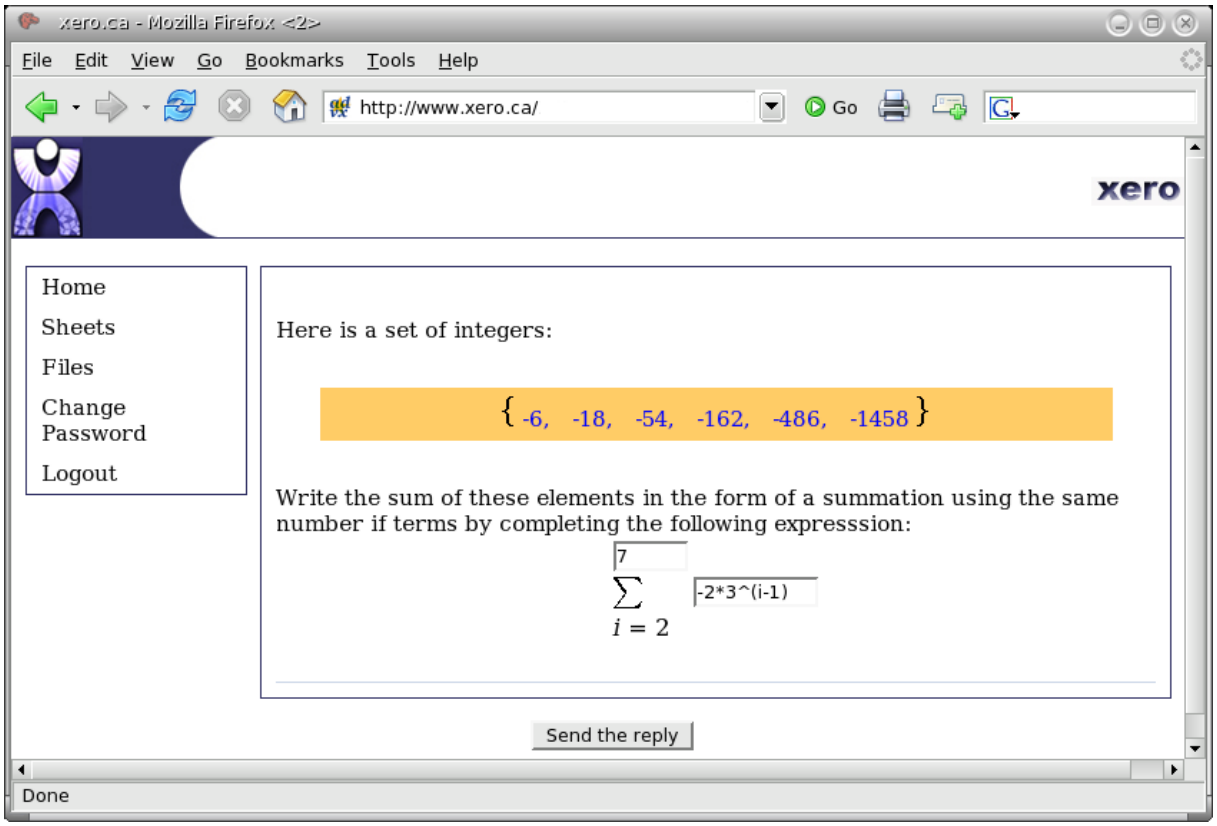

Figure 1: Screenshot of a discrete mathematics exercise in the interactive homework environment *Xero*

In [7], the online assignments were compared to paper-based assignments and it was found that students answered 7-9 times as many questions online. Moreover, survey results revealed that, although students found the questions to be more difficult, they also found them to be more enjoyable (see Table 1).

The survey also collected qualitative comments, many of which suggested that students found that they had learned more from the online assignment. In particular, students liked the instant feedback of having solutions provided after each question and the control they felt over the achievement of their goals. It is clear from the comments that students almost universally found the online assignments to be both more challenging and engaging than paper-based assignments.

One reason for this broadly positive assessment may be that many students found this format to be game-like. Indeed, comments suggested that students found it to be "fun and entertaining" and "like a challenging game". Not captured in the surveys were the in-person comments made by many students to the instructor about it being quite exciting and like a "game show". Needless to say, these are not the types of comments that one expects from students who are required to take a mathematics course to fulfil a degree requirement for another major.

	Assignment #1 (Paper)	*Assignment #2 (Online)*	*About the Same*
Average number of questions answered	30	265	
Which assignment was more difficult?	13% (3/23)	74% (17/23)	13% (3/23)
Which assignment was a better learning tool?	17% (4/23)	74% (17/23)	9% (2/23)
Which assignment did you enjoy more?	14% (3/22)	82% (18/22)	5% (1/22)

Table 1: Summary of survey response results comparing paper-based to online assignments using *Xero*

What made the assignment game-like was the fact that, to improve his/her score, a student would have to repeat not a single question, but rather the entire assignment. This adds an immediate and increasing element of risk. As a student proceeds through the assignment, he/she is under *increasing* pressure to answer the next question correctly, for the cost of not doing so – the time spent on an unsuccessful attempt that would effectively be lost when the assignment is restarted – increases.

Given that popular game shows such as *Jeopardy* and *Who Wants to be a Millionaire*, which are based on participants answering "intellectual" questions, are so highly engaging, student comments about their assignments being like a television game show underscore the potential of the gamification of academic work. Indeed, there may be some useful ideas that can be derived from such shows.

In *Jeopardy*, three contestants compete against each other, by selecting questions from different categories with different dollar values. Buzzing in to answer a question comes with risk: incorrectly answering the question will cause one's score to decrease. This is done under an element of time-pressure. One particularly interesting element of most game shows have in common is that participants usually have the ability to *catch-up* at any time if they are far behind. In *Jeopardy*, this is accomplished with hidden Double Jeopardy questions that allow a participant to wager any amount, and by the Final Jeopardy question at the end of the game that allows a chance for any participant to become the ultimate victor.

In *Who Wants to be a Millionaire*, a lone contestant must battle through a series of multiple choice quiz questions, with four options for each question, for an ultimate possible prize of $1 million. Some key features of the game include guaranteed prize levels to which

participants fall if they answer some question incorrectly, and the three well-known "lifelines":

1. *Fifty-fifty:* This lifeline will eliminate two of the answers, leaving only two for the participant to choose from.
2. *Phone a friend:* The contestant may ask for advice from a friend.
3. *Ask the audience:* The player may ask the audience as a whole what they think the correct answer is.

The *Xero* assignments were not originally conceived of as a game. But because they are perceived by students as being game-like – a perception that appears to increase effort – it seems prudent to ask how they can be made even more game-like, so as to expand and harness this heightened degree of student engagement.

One obvious weakness with the current *Xero* format that requires students to get a better score on a complete set of questions to improve their assignment grade is that it could cause students to abandon their attempt if they miss several questions in a row and lose hope in their ability to recover. Features like a *catch-up* or a *lifeline* might encourage students who are struggling with an assignment to persist.

Discussion

It appears that gamification has the potential to increase both student motivation and engagement for completing homework. In the model we have proposed, students answer the same questions that they would have on an online homework system, but the questions are scored and sequenced in a more engaging fashion.

It could, of course, be argued that by gamifying the assignments, students will be engaged for the wrong reasons. Instead of pursuing intellectual stimulation, they will seeking the psychological rewards that a game provides. But this may be no different from what is found in existing educational structures – after all, many, or perhaps even most, students enroll in a mathematics course not because of intellectual curiosity, but because it is a degree requirement for another major. As such, many may view any assignment as a game: maximize their score while minimizing their effort. In fact, a university education, more broadly, may be seen as a game in many respects, with points (grades), levels (school years), badges (degrees), leaderboards (Deans' lists) and obstacles and goals (graduation). Our model would simply attempt to make the game better and, therefore, more productive in its achievement of learning outcomes.

In this paper, we have contrasted some game-design elements found in game shows with those in the gamification of education literature. The choice to compare to television game shows was rooted in the fact that the majority of shows that are found to be engaging by a broad spectrum of society actually deal with intellectual material.

It may, of course, be argued that adding an element of "risk" to an assessment tool could be seen as unfair, or could have the potential to demoralize students. In our study, students could potentially spend an hour or more on an attempt and yet fail to make it to the next level (i.e., improve their score). In our model, we allow multiple retries of assignments with feedback given immediately after each question, where students, in order to improve their score, must receive a better overall score than on they did their best previous attempt. But this really not that different from what often happens with a make-up test, where students typically voluntarily elect to write a make-up test after they have received feedback from their original test, and where, to improve the grade, a student must score better than their original attempt.

Conclusions

In recent years, gamification has become an increasingly popular topic in education research – a trend that is likely to continue. Yet, the gamification literature, to date, has paid little attention to risk, a central element in many successful games. We argue that by adding a mild element of risk to interactive mathematical assignments, it is likely that students will become more engaged and do substantially more homework questions.

Indeed, by borrowing ideas from popular games, such as quiz shows, it might be possible to develop even more engaging assignments in the future. In particular, one could exploit the advantages of gamification in a context where students answer their homework questions in an interactive software learning environment, without the need to employ additional visible extrinsic game elements – that is to say, the gamification need not be as evident and it could be highly efficient in the use of instructor, student, and software development resources.

Brief Biographies of the Authors

Dr. Pollanen is an Associate Professor in the Department of Mathematics at Trent University. He is a leader in the development of innovation in teaching and learning technologies for mathematics. His innovations earned him awards such as the 2009 National Technology Innovation Award and 2014 Desire2Learn Innovation Award.

Dr. Cater is an Associate Professor in the Department of Economics at Trent University as well as Acting Dean of Arts & Science: Social Sciences. His research interests include teaching technologies and the economics of education.

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