Development of an Educational Game Prototype: Assessing Knowledge Gain through Flow

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Abstract

This proposal presents a plan for studying knowledge gain as a result of flow (the psychological state that human beings achieve when enjoyment is stimulated while learning takes place as described by the American psychologist Csikszentmihalyi's (1996) (Beylefeld 933)) for iterative testing of the prototype for an e-learning game, *Pathogens Against the Body*. The target market for the game is undergraduates majoring in the biological sciences; the sample population for this study is undergraduate biological sciences majors at New Jersey Institute of Technology (NJIT). The independent variables under study comprise the factors relevant to flow as described by the instrument *EGameFlow*: concentration, goal clarity, feedback, challenge, autonomy, immersion, social interaction, and knowledge improvement. This instrument will be administered to students after the game play phase of the study has completed. The dependent variable is the difference in scores on the knowledge test before and after game play indicating knowledge gain and hence success in the game. The study is in three parts: 'Before Game Play', 'During Game Play' and 'After Game Play'. Students will be assigned to one of three groups depending upon their familiarity with games similar to the prototype in the 'Before Game Play' phase. They will also play the game to learn it at this time. In the 'During Game Play' phase, they will play the game collaborating in teams of four. Information related to the meta-cognitive strategies of self-recording, modeling, and thinking aloud will be collected during this phase and the affective learning factors of interest and motivation will be assessed. During the 'After Game Play' phase, round robin discussions on student's experiences playing the game will be held. Statistics will be calculated for student knowledge test scores, *EGameFlow* scores, and their correlations using SPSS software. In addition, qualitative analysis will be performed on the verbal and hand written information collected. Information gleaned from analysis of information gathered during the study will inform modifications to the prototype. It is anticipated that the prototype will undergo several iterations of this

study (or a variation of it), refining the prototype with each iteration. Scholars are split concerning the effectiveness of e-learning games as an educational tool; research similar to that in this study will support the effort to develop high quality educational games.

Background

Research Problem

The research problem this study investigates is whether flow (the psychological state that human beings achieve when enjoyment is stimulated while learning takes place as described by the American psychologist Csikszentmihalyi's (1996)) in an e-learning game leads to knowledge gain. This descriptive and relational study will center on game play with a prototype for the e-learning game, *Pathogens Against the Body*; the idea for which I came up with for my PTC 629 Theory and Practice of Social Media class project. I would like to develop this game into a commercial product. Currently, my conceptual vision is a simulation of a dog's body under attack by pathogens. Students of the biological sciences could use the game to learn microbiology. The main idea is that they would choose a pathogen and create an avatar that creatively represents their pathogen. Through collaboration or working alone, students would employ their avatars to carry out tactics against the dog's body (the system) as their pathogen would, and the dog's body would respond to ward off the attack. The goal of the game is to inflict maximum damage on the dog's body, and at the same time, learn about microbiology, physiology, and immunology.

The game will be developed according to user-centered design techniques and standard iterative soft ware methodology. Activities required from this initial concept phase to development of the first workable prototype will not be covered in this study. Instead, this study begins with the testing of that first workable prototype.

Theory Under Investigation

This project will involve two main theories, new media theory and socio-cognitive theory; specifically, new media theory as it relates to educational games and socio-cognitive theory as it relates to meta-cognitive strategies of learning and affective learning.

New media theory. Digital learning provides students with an environment whereby they can develop skills in self-initiated learning and thereby become “active constructors of knowledge.” The progress in digital technologies has allowed for the development of games that spark student’s curiosity and inner motivations by providing entertainment, encouraging player immersion, and enhancing social interaction while posing challenges, and competition. As such, the main goal of e-learning games is to convey knowledge through the gaming experience, and this effectiveness of knowledge gain is an important criterion to consider in the evaluation of e-learning games. According to Fu, the evaluation tools developed thus far have targeted usability in commercial games designed for leisure purposes and cannot properly measure knowledge gain in e-learning games, and the tools developed to measure e-learning do not take into consideration fun and challenge as essential factors for motivating users to learn (Fu 101). In response, Fu created the *EGameFlow* scale, which is used in this study, to assist game designers assessment of their games from the learner’s point of view. The *EGameFlow* scale is an adaptation of Sweetser and Wyeth’s scale, *GameFlow*. He writes that “Sweetser and Wyeth (2005) combined various heuristics on usability and user experience in games into a concise model of enjoyment in game evaluation” (Fu 102). Their scale is modeled after flow experience proposed by Csikszentmihaly. Fu replaced Sweetser and Wyeth’s category of player skills with knowledge improvement to more closely relate to e-learning games. Fu designed his scale with eight factors: concentration, goal clarity, feedback, challenge, autonomy, immersion, social interaction, and knowledge improvement.

Socio-cognitive theory. Computer games are an effective learning environment “because they are a form of play that motivates students through entertainment” (Kim 800). Kim provides a literature review. He quotes various authors on the topic of games and learning; “interactive learning environments allow learners to construct understandings by interacting with information, tools, and materials as well as by collaborating with other learners within the game” (Dickey, 2007). “Games are seductive, deploying rich visual and spatial aesthetics that draw players into fantasy worlds that seem very real in their own terms, exciting awe and pleasure" (Poole, 2002). "To put it simply, games are engaging. They motivate students using entertainment, and this is a part of the natural learning process in human development" (Bisson & Luckner, 1996). Huk notes that affective variables as well as motivational factors are important to learning. Goal-based scenarios motivate learners when the scenarios are deemed authentic by learners. Huk has shown that a combination of cognitive and affective support was effective in increasing student's understanding of concepts presented during game play.

Amory points out that games that are structured as *learning from* whereby the game acts as the tutor, do not have the cognitive tools for the construction of new knowledge as do games that are *learning with* (Amory 811). *Learning with* games are characterized by learners taking part in game design, being mentored by experts during game play, collaborating with others, and solving puzzles, challenges, or problems.

Kim notes that problem solving strategies in game-based learning "may be a factor for high achievements in both learning and gaming. This implies that higher scores in learning and gaming require better problem solving abilities, which require, in turn, well-chosen strategies for both learning and gaming." (801). He notes that meta-cognitive strategies play an important role in problem solving in games. Kim defines meta-cognition "as the ability to understand and monitor one's own thoughts and the assumptions and implications of one's activities" (Kim 802). His meta-cognitive strategy is used in this study. The strategy encompasses three main parts: Self-recording – a writing activity, Modeling – a watching activity, and Thinking aloud – a listening and speaking activity. Students perform these activities before, during, and after game play.

Dormann writes that the dimensions for affective learning are emotional, social, aesthetic, moral, spiritual, and motivational. She has adapted the usability 'cognitive walkthrough' to affective learning whereby during game play, the researcher asks about four questions pertaining to a dimension of affective learning. The overall question for interpretation is how these affective experiences influence the experience and goals in game play. I chose to use Dormann's method to gain information about motivation in this study. According to Zaharias, the most important affective learning factor is motivation to learn; he therefore developed his questionnaire-based usability evaluation method for e-learning applications upon it (76). (I did not use Zaharias' instrument because it was developed for the evaluation of corporate e-learning courses, not educational games.)

Research Design

Variables

The independent [x] (predictor) variables for my research design will be student's flow (enjoyment while playing the game) as measured by Fu's *EGameFlow* scale. *EGameFlow* measures enjoyment offered by e-learning games in order to increase a designer's understanding of how the game affects flow or enjoyment from the learner's point of view.

The eight factors the *EGameFlow* scale measures are concentration, goal clarity, feedback, challenge, autonomy, immersion, social interaction, and knowledge improvement.

Concentration - activities in the game encourage the player's concentration while minimizing stress from learning overload (which may lower the player's concentration on the game).

Clear Goal - tasks in the game are clearly explained in the beginning.

Feedback – feedback in the game allows a player to determine the gap between the current stage of knowledge and the knowledge required for ultimate completion of the game's task.

Challenge – challenges fit the player's skill level and increase in difficulty as the player's skill level increases.

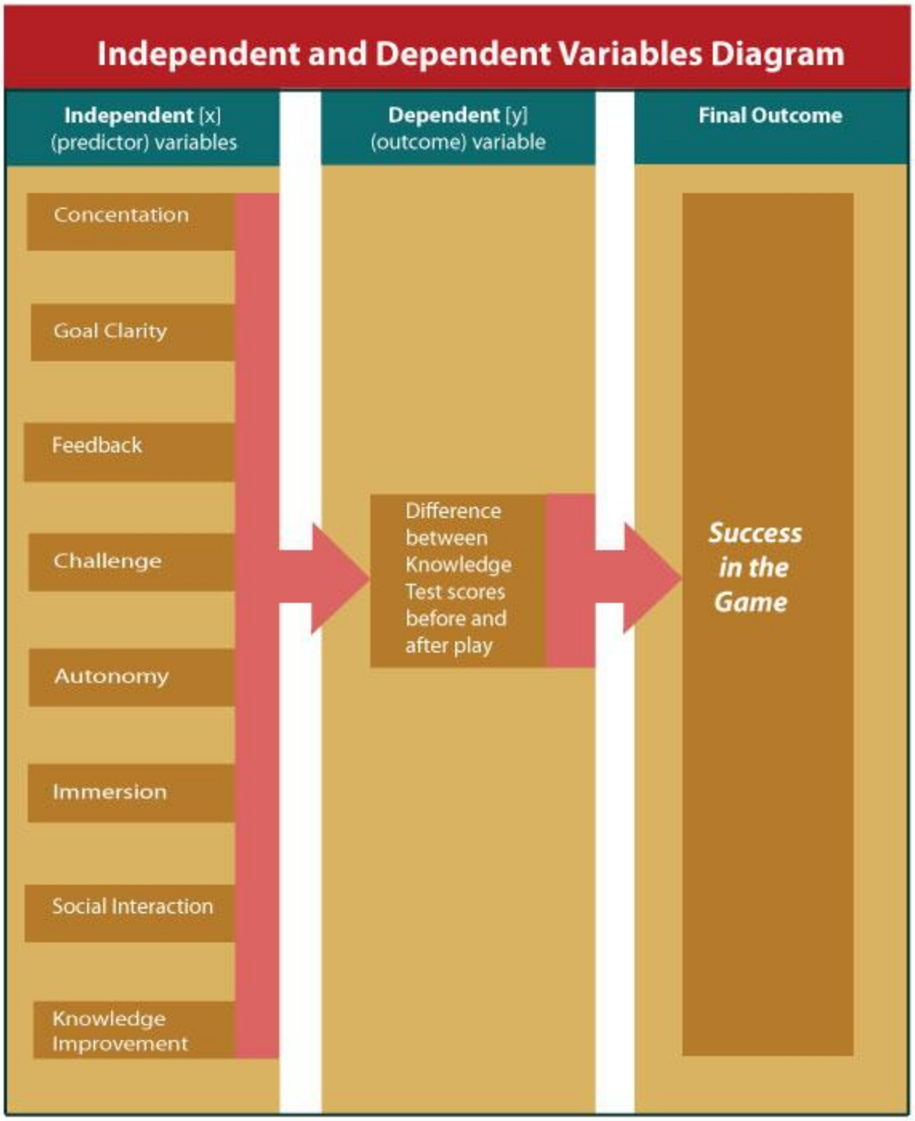
Autonomy – provides the ability for the player to assert total control over his or her choices in the game.

Immersion – leads the player into a state of immersion.

Social interaction – provides tasks that allow players to interact socially.

Knowledge improvement – increases the player's level of knowledge and skills while meeting the goal of the curriculum.

The dependent [y] (outcome) variable will be the difference between scores received on the knowledge test before and after game play indicating success of the game; that is, the degree of learning achieved by playing the game. The diagram on the following page shows a visual representation of the relationship between the independent and dependent variables.


Independent and Dependent Variables Diagram
Independent [x]
(predictor) variables
Dependent [y]
(outcome) variable
Final Outcome
Concentation
Goal Clarity
Feedback
Challenge
Autonomy
Immersion
Social Interaction
Knowledge
Improvement
Difference
between
Knowledge
Test scores
before and
after play
Success
in the
Game

Validity

The construct I am studying is successful student learning through the *Pathogens Against the Body* educational game prototype.

Construct Validity. The knowledge test will capture student learning with the game prototype. The knowledge test questions will be structured to cover concepts learned by playing the game. The test format will be multiple choice questions with a confidence factor. The same knowledge test will be given before game play and after game play. The difference in scores will be indicative knowledge gained by playing the game and learning success.

Criterion validity. Criterion validity will be established by the relationship between the *EGameFlow* scale and the Knowledge Test. It has been found that as student's enjoyment playing the game increases, their knowledge in the concepts learned through the game increases as well. For example, Dede found, that overall, students (regardless of gender, ethnicity, or language) broadened their knowledge through collaborative play in a multi-user virtual environment. The study took place in a historically accurate 19th century city in which students working in teams of three or four investigated why people were getting sick and what could be done to remove sources of the illness.

Content Validity. I believe that *EGameFlow* will be a valid instrument for me to use. The *EGameFlow* scale was developed by Fu, et al. in accordance with scale-development theory and methods as proposed by DeVellis. The resulting scale was tested for validity and reliability. *EGameFlow* is based upon *GameFlow* by Sweeter & Wyeth, a usability scale to help designers measure enjoyment of a game, and used by other scale developers and cited by other game researchers. However, *GameFlow* does not measure knowledge gain. Therefore, *EGameFlow* extends *GameFlow* by including questions on knowledge improvement from e-learning games developed by Chu et al.

Reliability

Fu notes that there has been little research into the evaluation of e-learning games, and not surprisingly, I was not able to find other research that used the *EGameFlow* instrument. But nevertheless, *EGameFlow* is based upon *GameFlow* which has been cited by other researchers and endorsed by Bernhaupt, Eckschlage, and Tscheligi, editors of ACE’07 International Conference session, How to measure usability, as a viable concept to evaluate user experience in games. Fu writes that *Bloom Taxonomy of Educational Objectives* classification for increasing knowledge is widely accepted by researchers; Fu and colleagues further developed the Bloom classification for measuring the improvements in knowledge derived from e-learning games. He indicates that improvement in knowledge is missing from *GameFlow,* and therefore included it in his instrument, *EGameFlow*.

The Knowledge Test will be deemed to have reliability as it will be written by an educational subject matter expert in the biological sciences. The Knowledge Test will consist of multiple choice questions based upon the concepts to be learned with the game

Process

A standard iterative software methodology will be followed to develop and test game prototypes. This process involves developing an initial prototype, testing that prototype, updating it per the recommendations and retesting. As this iterative process continues, the prototype approaches a fully functioning product. The game is currently in the conceptual stage and therefore, the prototype has not yet been designed. Steps to bring the prototype through the design stage to the point of development for testing are outside the scope of this research study and will only be mentioned briefly. To inform this initial design, focus groups with subject matter experts, gaming/virtual world experts, educational technology experts, and students will be held. A competitive analysis and heuristic evaluation will also be done. Before the prototype is put through this study, it will be tested to ensure that it is stable enough and bug-free enough to support the study.

The study will be conducted in three parts, ‘Before Game Play’, ‘During Game Play’, and ‘After Game Play’. During the ‘Before Game Play’ students for the study will be chosen, acclimated to the study process, and take the quantitative test and begin qualitative information recording. The ‘During Game Play’ phase will consist of several sessions whereby students will play the game, collaborate, and record their activities and feelings. During the final ‘After Game Play’ phase the quantitative test and questionnaire will be administered and qualitative information recording will be finalized. Also, round robin discussion groups will be held.

During the ‘Before Game Play’ phase randomly selected students from the sample population will be evaluated for their familiarity with games similar to the prototype game – not familiar, familiar, and very familiar. From these three groups, four students will be randomly selected. In preparation for the game play phase of the study, the selected students will learn to play the game until they reach a prescribed level of proficiency (for example, they must be able to perform selected major functions of the game).

Once study participants reach the prescribed level of proficiency playing the game, they will take part in the following ‘Before Game Play’ activities:

- learn the meta-cognitive skills of self-recording, modeling, and thinking aloud,
- take the knowledge test,
- choose a pathogen, and create an avatar,
- write their first self-recording entry about what they know and don’t know about the selected pathogen,
- identify the game missions and the activities required to achieve those missions, and
- select a target player to observe during the game play phase of the study.

Next, the ‘During Game Play’ part of the study will take place. This phase of the study will be conducted over several sessions thus allowing students to play the game, collaborate within their groups, observe others, and formulate and employ strategies. Students will have a specified time period within each gaming session to observe and consult with their selected players. They will then analyze the observed student's strategies and formulate their own strategies to use in subsequent gaming sessions. And, while game playing students will be encouraged to think aloud; that is, working within their groups, they will consult resources on their pathogen and discuss strategies, missions, and activities. At specified times during the game play session, students will be asked to stop game play. At this time, they will write self-recording entries about their activities since the prior self-recording entry and determine whether those activities are related to the game mission or not. In addition, an 'Affective Walkthrough' will be conducted whereby the research will ask about four questions to assess the student's affective experience, primarily as it relates to interest and motivation. In addition, this phase of the study will be videotaped and observed by the researchers.

After the game sessions have ended the study will move to the last phase, 'After Game Play.' During this final phase students will take part in the following activities:

- retake the knowledge test,
- complete the *EGameFlow* questionnaire, and
- reflect upon their game play experiences, and write their final self-recording entry.

In addition, students will be randomly selected to participate in Round Robin discussions about their experiences in the game.

Sampling Plan

Since the game is targeted towards undergraduates, the sample will include undergraduate students (both Full Time and Part Time) at NJIT whose major is Biology. From information in the literature, gender, ethnicity, and language were not factors; therefore, I will consider the population as a whole (although the actual proportion of undergraduate males to females in majoring in Biology is fairly equal – 45% to 55%).

The sampling plan will be Simple Random. The list of all Biology undergraduates will be numbered and the sample will be selected by selecting numbers from a random table.

In 2010 there were 228 undergraduates in the Biology program. I am assuming that that enrollment number does not changed significantly year-to-year.

For the maximum sample size at a 95% confidence level, and the maximum error of .3, the sample size is 117.

$n = Z^2 \text{ sigma}^2 / d^2$

Where

Z is score associated with the confidence interval

sigma is the standard deviation of the population

d is the derivation that can be tolerated between the sample mean and the true mean

$n = (1.96)^2 (1.65)^2 / .3^2$

$n = 116.2$ Round up to 117

Since the above formula assumes an infinite population, the sample can be reduced to 78 by use of the sampling adjustment formula.

n prime = n / 1 + (n /N)

Where

n = the sample size

N = the population of students

n prime = 117 / 1 + (117/ 228)

n prime = 77.48 Round up to 78

But for a study that incorporates qualitative research such as the one proposed here this sample size is very large; analyzing the results would be too time consuming. Therefore, in order to increase homogeneity into the sample so that the sample size can be reduced, a survey that measures familiarity with games similar to the prototype game will be given to the randomly selected 78 students. From that survey, students will be segregated into three groups, those who are not familiar, those who are familiar, and those who are very familiar. From those three groups, four students will be randomly chosen (using the simple random method as above) from each group to participate in the study creating three groups of four students.

Since the development of the prototype will be an iterative process, the study will be conducted over several versions of the prototype; and therefore, has a good chance to come close to using the optimal sample size of 78 students.

Information analysis

The information I collect will be analyzed quantitatively and qualitatively.

Quantitative information will be gathered with the knowledge test and the *EGameFlow* questionnaire which will consist of closed-end questions. Qualitative information will be gathered with the self-recording, modeling, and think aloud activities of the students as well as the videotape and round robin discussions.

The knowledge test, administered before game play and after game play, will consist of multiple choice questions that cover the concepts to be learned in the game. Each question will provide three choices and a confidence scale. The confidence scale will be based on a 4 point Likert scale: 1 – not confident, 2 – somewhat confident, 3 – confident, 4 – very confident. Students will select the statement they think best answers the question and then will indicate how confident they are that they chose the correct answer. At this point I do not know how many questions will be in the knowledge test, but I would think no fewer than twenty and no more than fifty. To understand if knowledge was gained during game play, using SPSS, the descriptive statistics mean, range and standard deviation will be run on the before and after scores and confidence levels for correct and incorrect answers. In addition, the correlation between before and after scores for all students as a whole as well as between students in the same group will be calculated with Cronbach's α and Pearson's correlation coefficient. To understand the knowledge gained on an individual level, a Paired Sample t-test for each student will be run on his or her before and after scores and confidence levels. And to understand the knowledge gained between students in different groups, Independent Sample t-tests will be run before and after scores of students in different groups.

The *EGameFlow* questionnaire consists of forty two questions: concentration – 6, goal clarity – 4, feedback – 5, challenge – 6, autonomy – 3, immersion – 7, social interaction – 6, and knowledge improvement – 5. Fu noted that the *EGameFlow* questionnaire was developed using a seven point Likert scale. I believe seven points would be too granular so I will instead use a five point Likert scale: 1 – strongly do not agree, 2 – do not agree, 3 – neither agree nor disagree, 4 – agree, 5 – strongly agree. To understand the degree of flow students experienced, using SPSS, the descriptive statistics range, mean, and standard deviation will be run on the results of the questionnaire. In addition, to understand if flow was influenced by familiarity with games similar to the prototype, Cronbach's α and Pearson's correlation coefficient will be calculated for scores between groups of students. To understand how flow was experienced for each factor, the same descriptive statistics will be run as well as Cronbach's α and Pearson's correlation coefficient.

In addition, to understand the correlation between the knowledge test scores delta and the factors measured by *EGameFlow* statistics such as Cronbach's α and Pearson's correlation coefficient will be calculated using SPSS.

Qualitative information such as participant's thoughts and experiences will be extremely important to the successful refinement and implementation of the prototype into a commercial product. Qualitative information collected during the study includes the meta-cognitive activities self-recording, modeling, and thinking aloud as well as the affective walkthrough questions and answers, researcher's observations, and round robin discussions. Transcripts will be made from the videotapes.

The meta-cognitive information will be coded to understand the student's thought processes throughout the game as it relates to an increase in knowledge. The 'Affective Walkthrough' will be coded to understand the student's interest and motivation levels throughout the game. And the round robin discussion groups will be coded to understand the student's experiences as they reflect back on the game.

Possible Problems

Possible problems that may occur include attrition of participants; not all participants may show up for the study, and or not all participants my see the study through to the end. Another problem is that students may not want to be videotaped. And lastly, participants may not write adequate the self-recording summaries.

Potential Solutions

To reduce the number of no-shows, I will remind participants of the study before the first session. It's important for the student's to collaborate during game play so a minimum of three in a group is satisfactory. To buffer against students not seeing the study through I will recruit four students per group. That way, if a student does drop out, the group can continue to carry on. The consideration of being videotaped will be addressed by letting participants know up front, before they fill out the initial familiarity questionnaire, that they will be videotaped. If they do not concur, then students will randomly be selected from the remaining students in the sample population to take their place. To ensure that self-recording summaries are adequate, participants will be monitored. For self-recording summaries that are not adequate, the monitor will point out to participants how they can improve their self-recording.

Time Line

The proposed research study will occur over several sessions. Sessions will be held before the study begins to allow students to learn the game, followed by several sessions of game play during the study. After the study round robin discussions will be held. In addition, time will be required before the study to develop the knowledge test and after the study to analyze the information gathered. This timeline includes activities related to the study itself, and not to development of the prototype. Research, writing, and review of the knowledge test will take three weeks.

Recruiting participants to fill in the initial familiarity questionnaire (including finding replacement students for those who do not want to be videotaped), compiling the results, and determining the groups will take two weeks.

Kim notes in his research on meta-cognitive strategies, participants learned the game over a ten week period, forty five minutes a day twice a week. I do not think the student's will require that amount of time to learn the prototype for this study. I would think they could learn it in less than half the time – one hour twice a week for three weeks.

Administering knowledge test and instructing students about meta-cognitive strategies during the 'Before Game Play' phase will take two days.

The 'During Game Play' phase will occur in sessions twice a week for one to two hours over four weeks.

Administering the knowledge test and EGameFlow questionnaire as well as writing the final reflective self-recording entry during the 'After Game Play' phase will take one day.

Round robin discussions will take one day.

Transcribing, coding, and analyzing the qualitative information and analyzing the quantitative information will take eight weeks.

Significance

E-learning games are a fairly recent development. And consequently, not much research has been done on knowledge gain and affective factors in educational games. Kim writes that with the progress made in digital learning technologies, e-learning games are a feasible tool. Although educators have emphasized the benefits of learning with games in children, they are split concerning e-learning games. Scholars who support e-learning games look to the technologies and people using those technologies and believe they will come to expect games incorporated into their learning activities. On the other hand, scholars who do not support e-learning games claim that "high-quality" educational games are not available. Kim concludes therefore, that the effort to help develop qualified games is invaluable. With this e-learning game, I am striving to do just that – provide an online learning game which promotes knowledge gain through entertainment, mission, social interaction, and player immersion.

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