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Increasing Online Information Retention: Analysing the Effects of Visual Hints and Feedback in Educational Games

Eric Zeglen, Pennsylvania State System of Higher Education
Joseph A. Rosendale, Indiana University of Pennsylvania

Abstract

Although online education offerings continue to grow in the higher education marketplace, issues of student achievement and course rigour still challenge the underlying instructional model, and alignment with institutional missions. Pedagogically, instructors and course designers can mitigate these issues by leveraging technology to further enhance students' cognition and knowledge retention within the online domain. This study analysed the effects of visual hints and elaborate feedback embedded in serious educational games to determine the effects on student learning and information recollection. Using a quasi-experimental design and quantitative testing methods based on differing forms of feedback in the game, significant differences were found among three groups of students in an online educational environment. Mean scores on comprehension tests indicated that participants who were exposed to elaborate feedback and visual hints performed better than control groups in an online learning environment. This supports the underlying framework of information processing theory.

Keywords: Online learning; visual hints; educational games; distance education; delayed feedback

Introduction

Online education is a fundamental and systemic variation from traditional forms of higher education and is, in part, a response to an exponentially changing global marketplace. Distance-based instruction has become ubiquitous in twenty-first century college and university teaching and, as growth projections estimate a 13.9% increase in overall higher education enrolment by the year 2022 at degree-granting institutions (National Center for Educational Statistics, 2014), the numbers of fully online education programmes will continue to rise. Further, recent data reported by the Babson Survey Research group shows that student enrolment in online education in the United States has increased (3.7% in 2014 and 3.9% in 2015). In addition, 63.3% of academic leaders reported that online learning is critical to their long-term strategy (Babson Study, 2015).

Innovation lies at the heart of higher education, and leveraging technology to enhance access to learning experiences while maintaining institutional quality will be the next wave of systemic change and strategic planning (Cavanagh & Thompson, 2016). While overall total institutional enrolment has stagnated recently in higher education in the United States, the distance education segment is one consistent area of growth (National

Center for Educational Statistics, 2014). However, ensuring online courses deliver the same (or higher) quality learning experience as face-to-face classes is a key issue. From the perspective of potential employers and hiring personnel, one of the main challenges to online and open educational offerings at present is the rigour and veracity of the offerings and overall student learning and outcomes (Adams & DeFleur, 2006; Rosendale, 2017). Similarly, the one-size-fits-all instructional pedagogy predominantly found in asynchronous online courses results in significantly less knowledge retention than does the personalised instruction common in traditional face-to-face courses (Lindsey, Shroyer, Pashler, & Mozer, 2014).

One way to counter claims of reduced efficacy in online classes is by integrating meaningful, curriculum-supported educational games which can enhance critical thinking, provide more flexible interaction, and increase overall course performance when used with other pedagogical strategies (Betts, Bal, & Betts, 2013). At present, much of the literature regarding the use of games in online education focuses on the engagement or motivational value rather than the achievement of learning objectives. Of greater importance, however, is the legitimacy of online games in better facilitating class content and the achievement of course objectives. Thus, the purpose of this report is to determine whether exposure to specific learning strategies during in-course game play has any effect on an individual's ability to retain information.

Related literature

This paper emphasises the need for user-controlled learning in online environments and focuses on asynchronous learning. Using feedback juxtaposed with instructional content at the process level—when learners are actively learning—helps to focus the learners' information processing, which can be more effective for the student (Hattie & Timperley, 2007). In a systematic review of studies researching the use of feedback, Hattie and Timperley (2007) identified several major themes—one of which was the most effective timing of feedback to promote learning. Building on this research and methodology, this study placed elaborate feedback in the instructional module rather than providing feedback in the formal assessment.

In a study of post-graduate students who were participating in an online course, Coll, Rochera, and Gispert (2014) found that elaborate feedback tended to promote knowledge building when the complexity of feedback was varied. Coll et al. (2014) targeted post-graduate students, who would have had more declarative and conceptual knowledge than the subjects of the study in this dissertation, who were traditional undergraduate students in their first year or two of post-secondary education. As such, the undergraduate participants might be expected to gain more benefit from experiencing a gaming environment to deliver the instructional material and elaborate feedback. Additionally, the use of feedback in an online environment can be influenced by intermediary variables such as self-regulation. When instructional designers include feedback as a learning strategy to assist with reducing detrimental variables, learning can be enhanced (Lee, Lim, & Grabowski, 2010). The study by Lee et al. (2010) speaks to one of the foundational aspects of this study by understanding the effect of learning strategies by course developers.

Providing elaborative feedback after a student fails a question can yield more positive results in desired behaviour than allowing students to repeat the task while receiving only verification feedback (Narciss et al., 2014). The methodology used by Narciss et al. (2014) tested the effect of elaborate feedback; however, this was measured against the effect of repeated attempts by subjects who received only verification feedback. Effects of such feedback ripple beyond the positive consequences for student learning. A study conducted by Espasa and Meneses (2010) found that improvement in student achievement was accompanied by increased levels of overall satisfaction with the course. Although not measured in the current study, the gamification of the instructional module should also increase student engagement and satisfaction.

The dynamics of feedback affect the instructor and learner in three main ways: feedback can motivate learners to improve their performance; learners can use feedback to validate or change their response; or feedback can satisfy a learner's need for positive reinforcement (Kulhavy, White, & Topp, 1985). Underlying these factors is the cognitive process that occurs in the learner to transfer knowledge from working memory to long-term memory, thus facilitating an understanding of the material for future retrieval (Buchwald & Rapp, 2009). Moreover, elaborate feedback that scaffolds information from an entire online learning module has been found to increase student test scores more than verification feedback and isolated or single-unit elaborate feedback (Lin et al., 2014). The methodology used in this study builds on these findings by using a gaming environment with questions and associated elaborate feedback. The material is grouped according to the progression of the instructional material. Segedy, Kinnebrew, and Biswas (2013) conducted a study to find out whether feedback in a contextualised and conversational format in a computer simulation had any effect on student achievement. They found that contextualising the feedback for the goal of the simulation, and providing feedback in a conversational format, resulted in a significant increase in the students' ability to understand the material. The findings of this study support the concept that elaborate feedback that is not verbal or face to face can be effective in the teaching and learning process.

If immediate feedback in online learning is important, the concept of educational gamification is equally so. Indeed, games can function as a motivational rehearsal to increase a student's interaction with the instructional material. To achieve this outcome, games must be sustainable, meaning they must be designed to challenge and entertain students, allowing them to remain motivated and focused on the material (Eseryel, Law, Ifenthaler, Xun, & Miller, 2014). Similarly, Burguillo (2010) concluded that features such as quests, fantasies, and challenges in an educational game had a positive effect on students' learning abilities and knowledge construction. A study conducted with high-school-aged students used a video game to teach them how household electrical appliances use electricity, how to calculate energy consumption, and the facts of basic energy conservation. When tested on their conceptual understanding of the topic, the study concluded that students playing the game significantly outperformed those who did not (Dorji, Panjaburee, & Srisawasdi, 2015). Educational games can also benefit upper-division undergraduate students when they are used in online instruction. Research conducted with upper-division medical students found that learners using a game-based learning module performed significantly better on cognitive knowledge tests than those who were not exposed to the game-based learning module (Boeker, Andel, Vach, & Frankenschmidt, 2013).

Literature on gaming is just beginning to shift focus from motivation-, engagement-, and entertainment-based games to serious educational games. As gaming in online education has become more prevalent over time, serious educational games have been developed and the research has shifted towards games that are developed purposefully for education. However, much of the research today still focuses on the merits of games in education and not on the educational effect the game design has on achieving desired learning outcomes for each specific course.

A mixed-methods approach conducted to study the effects of using a game-based course for American history found that students using the game spent more time reviewing the course material than those in the control group (who used a non-game-based online course). The increase in time spent with the course material led to a significant performance difference between the two groups. Qualitative findings indicated that the story and presentation of the instructional material contributed to student motivation (Hess & Gunter, 2013). Further, students using a serious educational game to learn British literature performed better than students learning the same material without the game (Mansour & El-Said, 2009). The researchers observed that the game increased the social interaction among the students, who initiated game play outside the formal classroom. They concluded that this increase in social interaction about the instructional material contributed to the performance differentiation between the two groups (Mansour & El-Said, 2009).

Serious educational games have also proven to be effective in achieving targeted behaviour beyond the classroom. Using games to teach adolescents the negative consequences of alcohol and drug use has been shown to be effective in reducing use. This research not only provides evidence that learning outcomes can be improved by using games, but also that attitudes and behaviour can change as a result of serious educational games (Rodriguez, Teesson, & Newton, 2014). The research in this study does not presume to address all of the gaps in the available research. However, it does attempt to shift the focus from gaming's motivational and entertainment qualities to its capacity to promote learning, and to advance the field by unifying traditional learning strategies and digital gaming environments.

Bellotti, Kapralos, Lee, Moreno-Ger, and Berta (2013) identified three requirements for a serious educational game. Firstly, a game needs to be fun and entertaining. Secondly, the game needs to be educational. And lastly, the game must enable students to be assessed on the instructional material incorporated in the game. The researchers' assessment of serious game research also suggests that, as hardware and software advance, further research should be conducted to keep pace with changing possibilities. Similarly, Pløhn (2014) hypothesised that, if designed well, an educational game can motivate students to spend time working on the instructional material outside the classroom. He used a mixed-methodology approach to further understand students' interaction with an education quest game called *Nuclear Mayhem*. Findings supported his hypothesis: 87% of the logins occurred outside the classroom when no formal class activity was taking place. Student interviews identified the storyline, plot, and realistic nature of the game as their main motivation for playing the game outside the formal teaching environment.

Theoretical framework

The main theoretical lens through which this study is informed is information processing theory. The basic premise of this theory is that the way the human brain processes information is similar to the way a computer processes information and, when presented with extraneous information, the human brain will use working memory and associated processing to shift its focus from the desirable educational material. This causes cognitive overload, information loss, and the inability to transfer information to long-term memory. Cognition necessitates the processing of information, and information processing theory helps us to model and predict how humans receive, interpret, and store information.

As a theory of cognitive architecture, information processing theory is similar to, and contributes to, models of communication theory. Communication theory identifies a sender, a message (over a specified medium), and a receiver. During this process the message is encoded, and then decoded by the respective participant. Noise can affect the message or the decoding. Information processing theory helps us understand and predict how the receiver processes the information, and so bridges the gap between communication theory and cognition (Piccinini & Scarantino, 2011).

Designing digital teaching materials for use in modern online enhanced courses can be challenging. Perspective alone is not adequate; individuals designing a course using multimedia resources need to understand how the human mind processes information. According to Riuji (2012), online teaching resources can only be developed for maximum efficiency and effectiveness under the guidance of information processing theory and learning theories.

The mind's ability to process a finite amount of new information or cognitive load is closely linked to information processing theory (Paas & Ayres, 2014). When working memory processes new information, it has a capacity of three to five units for about 30 seconds. During this time, working memory accesses long-term memory to provide additional information. If the new information is not processed into long-term information within these limitations, the new information will succumb to information decay, and is therefore lost. Digital materials presented in online learning environments can enrich learning, but they can also prevent information from being processed by appropriating the learner's working memory and contributing to cognitive overload. Instructional material designers must consider cognitive overload by reducing the amount of noise when communicating information, thereby making the most efficient use of learning strategies (Kalyuga, 2012).

Information is processed through visual and auditory senses. According to Taylor (2013), instructional designers who incorporate visual aids and text in the same instructional module should integrate the two artifacts. This means the learner does not need to use the text to acquire information from the image, and so avoids the unwanted noise that contributes to cognitive overload. Additionally, the module should not be designed to address multiple learning styles (e.g., by using visual aids and audio prompts). Information should be delivered primarily in one channel, whether auditory, physical, verbal, or visual, to avoid interference that commonly occurs if multiple channels are used at once. Research has shown that combining text, visuals, and audio in the same module increases cognitive load (Clark & Mayer, 2011).

Methods

This research used a quantitative data collection approach. Materials were adapted from the Program of Systematic Evaluation (PSE) printed resources (Experimental Instructional Materials [EIM]), which were initially developed by Francis Dwyer and later modified by Richard Lamberski to include visual images to reinforce the textual components (Dwyer, 1982). Dwyer's protocol intended to examine the instructional effects of visualisation and instructional training environments on student information acquisition and retrieval. For this study, the main researcher used the Desire to Learn (D2L) learning management system and created a quest-style educational game called *Heart University*. In this game, participants used a predesigned avatar to travel through a fictitious university campus, stopping at online campus buildings (the defined waypoints) to complete activities that were designed as a series of course-based educational questions. The focus of the game was to explore how embedded games in online learning might affect users' information retrieval and learning comprehension.

To minimise the study's technical needs and to reduce their extraneous cognitive load, each learning module and associated image was adapted to be displayed in the D2L environment. The alternative was to use a presentation application such as Microsoft's PowerPoint or a newly developed Adobe Flash environment. However, the researchers determined that having subjects leave the D2L course might lead to subject confusion and confound the results of the study. In addition to the original instructional module, the researchers used D2L's Gamification module to study the effects of learner behaviour in a gaming environment. The original EIM instructional unit (common to all groups), the newly developed game, a demographic survey, and the associated EIM assessments were combined to form a course in D2L. By changing only the game in the course to apply the experimental treatments, the research had three courses for this study: The Control Group used course 1; Treatment Group 1 used course 2; Treatment Group 2 used course 3.

Participants in this study were college-aged students attending a mid-size public university in the Atlantic region of the United States. From a total of 415 students identified in a purposeful sampling method, 65 completed the protocol for this study. Students were randomly assigned to the Control Group (22 students), Treatment Group 1 (22 students), and Treatment Group 2 (21 students), respectively. Table 1 shows how the groups were treated.

Table 1 Treatments applied in Heart University game

Treatment	Brief description	Full description of Heart University game
Control Group	Instructional game with no learning strategies applied	Subjects were not informed of the correctness or incorrectness of their answers but had knowledge of their overall achievement in the game.
Treatment Group 1	Instructional game with elaborate feedback	Subjects received elaborate feedback after each game activity. Each game activity contained 1–5 questions. After completing an activity the subjects reviewed each question. They knew whether they were correct or incorrect and had elaborate feedback as to why. This group had an opportunity for rehearsal of the EIM instructional material with the additional reinforcement of elaborate feedback.
Treatment Group 2	Instructional game with visual hints and elaborate feedback	Subjects received elaborate feedback after each game activity. When presented with a question during game play this group also received a visual hint. Subjects were given the visual reinforcement (hint) before they answered the rehearsal question; they also received the same elaborate feedback as Treatment Group 1. This group was given the same visual/image during the assessment phase.

This study employed a post-test-only experimental design to investigate the effect that delayed elaborate feedback and visual hints might have on the achievement of learning objectives in a gaming environment. The study examined the effect of several independent variables—the learning strategies (delayed elaborate feedback and visual hints) in the game, and any interaction-specific demographic variables (age, gender, class standing, gaming experience and credits earned) which may have affected the game results. The study's dependent variables were achievement of learning objectives of each group, based on their performance on the identified three criterion measures and a comprehensive score. A subject's achievement of the learning objectives was measured by the individual and total scores of three assessments: an identification assessment, a drawing assessment, and a comprehension assessment. The total of all three assessments (a comprehensive score) was a fourth criterion measure.

Participants completed a confidential demographic survey and were then asked to read twenty online D2L units that contained instructional content adapted from the EIM materials on the parts and functions of the human heart. After reviewing all the instructional material, the subjects launched *Heart University* in D2L. The game presented the subject with 1–5 questions in each game activity. Each multiple-choice question had four or five possible answers, only one of which was correct. To select an answer, the student would select the "Record Answer" button and, depending on their answer, may or may not receive points toward a digital badge. As noted in Table 1, treatment groups 1 and 2 could review their answers and received elaborate feedback after the entire activity (1–5 questions) had been completed, while the control group received no feedback during gameplay.

Results and analysis

The main research question of this study investigated the effects on achievement of adding delayed elaborate feedback and visual hints in a gaming environment. To examine these effects, one-way analysis of variance (ANOVA) tests were conducted. The results are illustrated in Tables 2–4.

The first test was used to examine the scores on the comprehension test across the treatment groups. Levene's test was not significant (2.228); thus, an F-test was used for the ANOVA. Results of the ANOVA test did not show a significant difference between the groups, indicating that feedback, or visual hints with feedback, does not significantly affect comprehension. However, the mean score (m = 11.32) of the group that was exposed to elaborate feedback and visual hints was higher than the other two groups.

Table 2 One-way analysis of variance for comprehension scores

Treatment group	N	Mean	Std. dev.	Std. error	F-value	Sig.
Control	22	9.59	3.838	.818	.966 df = 2,62	.386
Feedback only	21	9.76	4.392	.958		
Feedback & visual hints	22	11.32	5.241	1.117		
Total	65	10.23	4.527	.561		

Note: Levene's = 2.228 (*df* = 2,62) *p* = .116

The second statistical test investigated the scores on the identification test across the treatment groups. Just as in the test for the comprehension scores, the Levene's test was not significant (.613); thus, an F-test was used for the ANOVA. However, as shown in Table 3, there is a significant difference between the three groups, revealing that the learning strategies used in the game did affect the transfer of information from working memory to long-term memory. Students who were given a visual hint and elaborate feedback scored significantly higher than students in the control group who were given neither elaborate feedback nor visual hints.

Table 3 One-way analysis of variance for identification scores

Treatment group	N	Mean	Std. dev.	Std. error	F-value	Sig.
Control	22	9.50	3.827	.816	3.724 df = 2,62	.030
Feedback only	21	10.00	3.347	.730		
Feedback & visual hints	22	12.55	4.585	.978		
Total	65	10.69	4.127	.512		

Note: Levene's = .613 (*df* = 2,62) *p* = .545

As with the comprehensive and drawing tests, Table 4 shows no significant difference among the groups. However, the mean scores of the control group and feedback group (Treatment Group 1) are close, and the group exposed to the feedback and visual hints (Treatment Group 2) has a much higher mean score. This could indicate that the effect of using elaborate feedback and visual hints in a gaming environment could affect transfer of information from working memory to long-term memory. Considering the significance level shown in Table 3, a larger sample size might yield a significant finding.

Table 4 One-way analysis of variance for comprehensive scores

Treatment group	N	Mean	Std. dev.	Std. error	F-value	Sig.
Control	22	32.86	9.548	2.036	1.839 df = 2,62	.168
Feedback only	21	32.10	11.045	2.410		
Feedback & visual hints	22	38.14	13.058	2.784		
Total	65	34.40	11.460	1.421		

Note. Levene's = .788 (*df*= 2,61) p = .459

Taking the small sample size into consideration, the overall results suggest that including delayed elaborate feedback and visual hints in a gaming environment does have a significant effect on transferring information from working memory to long-term memory. Specifically, these results indicate that, when students are given pedagogical reinforcement in a serious educational game, they are more likely to retain information and achieve the learning objectives.

Additional statistical testing was done to determine whether demographic variables had any mediating effects on overall student learning achievement. Tests conducted on variables such as age, gender, class rank, and prior exposure to gaming environments, did not produce statistically significant findings.

Conclusion

Driving forces such as technological advancement and pressures from many private, public, and governmental sectors to increase the education attainment rate in the United States have created an environment in which post-secondary institutions are spending more resources on online learning. To meet demands for high-quality academic programmes, and to make judicious use of resources, faculty and instructional designers must consider findings like those reported in this study. One such finding is that, to mitigate questions of learning outcome achievement and the overall veracity of online education, using serious educational games, visual reinforcements, and delayed feedback in an online learning environment should be considered.

The prevalence and growth of online technology for supplementing face-to-face education, and for fully online education, has provided more opportunities for faculty and learners. To ensure a quality experience and education, instructional designers and faculty must design the content in a manner that takes advantage of technological features and uses reliable pedagogical approaches. In support of this assertion, the findings in this study illustrate that the combined use of delayed elaborate feedback and visual hints in online courses do have a significant effect on an individual's ability to process information from working memory to long-term memory. By organising and presenting material in an environment that is familiar, engaging, and motivating, faculty and instructional designers can optimise learning modules to provide better opportunities for information to be transferred from students' working memory to long-term memory. Practitioners such as faculty, instructional designers, and games-based learning creators should work together to further research on the use of specific learning strategies in serious educational games.

Future research

Much of the research examining the use of digital games in education investigates the motivational and engaging effect such games have on learners. The research draws connections between student engagement, motivation, and the ability for students to learn. However, more research needs to be conducted, similar to this study, focusing on the qualities of the game that directly promote learning. The underlying question asked in this report is whether learning occurs as a result of the game's design. Breaking the design components of a game into smaller elements and investigating the effect of each component on the potential to promote learning provides specific information that may lead to more concrete strategies for faculty and instructional designers.

Research such as that in this study needs to be repeated as technology changes. As a result of shifts and advancements in technology, users will naturally experience extraneous cognitive load. For this study, the manner in which elaborate feedback and visual hints were delivered was constrained by the current technological environment. Other factors typically found in games (such as competition facets) can increase engagement and motivation, which could produce a significant effect when mixed with elaborate feedback and/or visual hints. A more longitudinal study conducted over multiple semesters where other aspects such as personal achievements are combined with elaborate feedback and visual hints could, over time, reduce extraneous cognitive load and have more of an effect on student achievement and learning retention.

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Biographical notes

Eric Zeglen, Ph.D.
ericzeglen@hotmail.com

Eric is currently the Executive Director of Academic Programs and Assessment for the Pennsylvania State System of Higher Education. Previously he has served in roles such as Director of Assessment and Academic Technology, Assistant Vice Chancellor for Academic Technology, and Chief Information Officer. His research interests include the application of online tools (such as virtual gaming and the use of learning objects) to traditional education.

Joseph A. Rosendale, Ph.D.
j.a.rosendale@iup.edu

Joe is Assistant Professor of Management in the Eberly College of Business at Indiana University of Pennsylvania. His main areas of instruction include business communications, organisational behaviour, and general management. His current research focuses on digital communication and higher education instruction as it pertains to workforce development and organisational training.

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