Games students play: Engaging first year tertiary students in linking and extending foundation material through the use of a digital game.

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Abstract

Digital game-based learning (DGBL) is a pedagogical process that can be incorporated into first year teaching and learning practice. The effectiveness of using a DGBL resource to engage first year biological science students in recalling, linking and applying foundation knowledge has been explored in the School of Human Life Sciences (HLS). Academics are increasingly frustrated that students are unable to link and extend first year first semester foundation material throughout their undergraduate degree. Sample questions from a pilot study of the resource suggest that the resource has effectively targeted a mixed cohort of students to retain, link and extend foundation knowledge. Our study suggests that DGBL resources have a valid role in enabling students to recall and transfer unit content into new learning domains.

Introduction

Foundation knowledge is a major component of first year unit content at university level and is the platform for developing and expanding learning in successive units, particularly in specific discipline based professional degrees. Traditional presentation methods (i.e., lecture formats) are particularly disengaging for today's students, tending to produce "uninterested pragmatists who cram for tests, commit the material to short-term memory, and quickly forget it thereafter" (Foreman, 2003, p.62). As a result, educational developers have embraced technology to develop complementary alternative learning resources. In the School of Human Life Sciences (HLS), we have developed a web-based multi-player interactive game fulfilling the criteria of digital game-based learning (DGBL) and using multiple choice questions to engage and motivate students in content linked units (Figure 1).

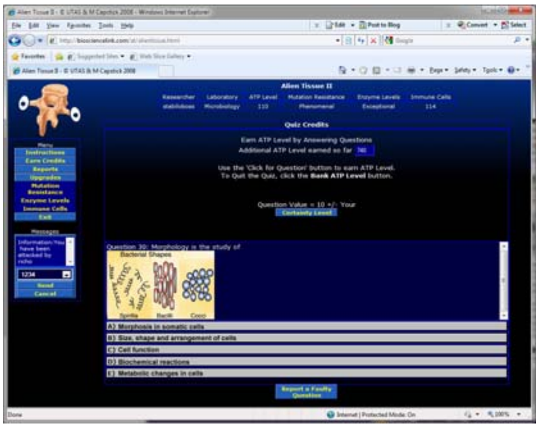

Figure 1. Screen capture of the DGBL resource

Digital game-based learning (DGBL)

DGBL is defined as "any marriage of educational content and computer games" (Prensky, 2001a, p.145) and is an ideal platform to engage first year student learning. DGBL resources have been available for a number of years but have increased in complexity and diversity since Web 2.0 applications became available post year 2000 (Alexander, 2006; Cheung, Yip, Townsend, & Scotch, 2008; Geith, 2008; Greenhow, Robelia, & Hughes, 2009; Jones, Ramanau, Cross, & Healing, 2009; Owston, 2009). There is also an increased expectation among the student population for sophistication in DGBL based on their own experiences of technology use.

Ideally, a DGBL resource should be constructed using a teaching methodology which includes a constructivist approach to knowledge transfer (Macaulay & Cree, 1999) using a spiral curriculum involving iterative processes of scaffolding (Kiili, 2007). In addition, one of the primary indications of successful game design is its ability to elicit emotional enjoyment in the player – i.e., if the game isn't fun, it won't be played or revisited. Humans who become overwhelmingly engaged in an activity are described as 'in the zone', or experiencing 'flow'. Flow is a model of emotional experience which is so gratifying, that people are willing to do it for its own sake (Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005). Thus, the creation of a state of flow by those wishing to deliver educational content is useful for engaging student learning. A model which integrates the essential game design elements required to maintain such immersion whilst generating learning outcomes has been developed (Pivec & Kearney, 2007). These essential elements are persistent re-engagement, player control, scaffolding of abilities, different learning types (e.g., skills-based, knowledge-based, effective), cognitive challenge and reflection.

Advocates of game-based learning recognise the psychological elements of play which contribute to the learning process and the pedagogy of play has been acknowledged from Piaget, to Vygotsky, to Gagne (Vygotsky, 1997). Van Eck (2006a) described four principles of learning in games, and related these to Gagne's nine events which align external educational contribution with internal processing. These principles are: 1) Games employ play theory, cycles of learning and engagement; (2) Games employ problem-based learning; (3) Games embody situated cognition and learning; and (4) Games encourage question asking through cognitive disequilibrium and scaffolding.

Immersing DGBL into the first year curriculum

'Digital natives' is a term which refers to the new generation of students, predicated around their exposure to, and use of, recent modern technologies (Prensky, 2001a; Van Eck, 2006b; Kennedy, Judd, Churchward, & Gray, 2008). Understandably, first year cohorts contain a large number of 'digital natives' whose expectations include the incorporation of sophisticated digital technology in their teaching and learning resources. An intrinsic shift in cerebral information processing mechanisms has occurred for 'digital natives' (Prensky, 2005), compared with those adopting this technology later in life. This needs to be considered by all staff involved in first year teaching and learning.

The inclusion and alignment of both game taxonomy and learning taxonomy (Van Eck, 2006b) in a resource has a profound influence on successful engagement and learning outcome. It is predicated around situating the game within the correct instructional platform to allow for both assessment and synthesis modalities. Consequently, meaningful and relevant context must form part of the design approach (Koepp et al, 1998).

Motivation, when applied to learning systems, is defined as "the process by which we consciously or unconsciously allocate working memory resources" (Brooks & Shell, 2006, p.17). Motivation leads to student engagement which is of paramount importance in any effective learning strategy. Digital games whose structures are competitive, utilise content information as currency (or a weapon) in gaming contexts, to motivate and encourage players to battle for intellectual supremacy (Herz, 2002). A survey conducted in 2005 to explore educators' attitudes to digital games in the classroom showed that the majority of United Kingdom teachers were open-minded about their usefulness (Futurelab, 2006). Motivation and competitiveness are therefore two key elements that must be incorporated into DGBL resources.

One of the goals of DGBL is to allow students to enter the game environment at their own level of expertise, and provide the means (scaffolding) for them to develop mastery by linking and integrating the knowledge gained. Scaffolding, in pedagogical terms, refers to the different kinds and amounts of support that a learner receives during the process of acquiring knowledge, and allows learners to “perform activities that they were unable to perform without this support” (Merrienboer, Clark & Croock, 2002, p.54). The support, in the form of interventions, can be through the educators (e.g., teacher, tutor) or by other means such as assistance mechanisms built into learning resources (e.g., feedback, just-in-time help).

HLS game project

The University of Tasmania (UTas) HLS pilot project involved the development and implementation of an online game to enable students to link content between successive HLS units in first year. There is a general assumption that skills and knowledge developed in first year will be transferable to other academic contexts and real life situations but, students are often unable to apply their skills and knowledge into new domains (Britton et al, 2005; Scott, 2005; Rebello et al, 2007). The transfer of core skills can occur under particular learning conditions supported and enhanced by curriculum design and specific pedagogical objectives (Justice, Rice, & Warry, 2009; Lobato, 2008). The methodology of the online game allows for a structured progression by linking and extending foundation knowledge with the increasing complexity of the curriculum content. There exists no current literature that DGBL resources have previously been used to address this transfer and linking of knowledge and core skills.

Students studying HLS science based degrees, study Cell Biology in semester one. This unit is a prerequisite for the semester two units, Anatomy and Physiology 1 and Microbiology and Health. The HLS online game incorporates content from the above units in a tiered game system to engage students in learning and retaining the unit material and, in recognising and applying cross unit content. It is interspersed with the introduction of new and more challenging concepts, thus allowing the combination of experiential and problem based learning methodology to create a balance between student boredom and student challenge and engagement. This resource enables students to recall foundation material from core units and to transfer and link knowledge and concepts, while engaging in a fun and stimulating learning environment.

The game is currently written using a combination of perl, html and javascript and is compliant for students with disabilities who use Dragon or Jaws software for computer access. The content of the unit is delivered in the game using multiple choice questions (MCQ). Each MCQ has five distractors, and one correct answer. The MCQ’s are written at differing orders of difficulty based around the domains of Bloom’s taxonomy of learning (Bloom & Krathwohl, 1956). This taxonomy is a framework for organising learning objectives related to curriculum development and assessment. The MCQ's are also written using the revised version of Bloom’s taxonomy (Anderson, Krathwohl & Bloom, 2001, p.30), where the domain categories (nouns) are converted into “their active verb counterparts”. For example, “knowledge” becomes recall or remember, and “application” becomes apply. The questions written at Bloom’s levels 3 to 6, which examine application, synthesis and evaluation, are regarded as testing higher order thinking. The content of the MCQ’s in the game varies from simple knowledge recall from the long term memory, to combinations of recall and/or application and/or analysis, evaluation and synthesis requiring both short and long term memory.

Feedback is available for most questions in the game. The content of the foundation MCQ’s is linked to similar, but more complex content areas throughout the first year units. This linking forms part of the feedback as the student progresses through related curriculum content. The feedback is designed as a help system (scaffolding) and is available as a choice to the game player. This is important as a study involving first year psychology students, demonstrated that computer games used as a learning resource are improved by the "addition of a help system that provides information to the user at the time that it is most required" (Sweetser & Dennis, 2003, p.49).

The game is designed to reward students for demonstrating and applying knowledge. The rewards increase in value according to the difficulty, application and linking of the conceptual knowledge which is required to correctly answer individual questions. There is a reward system for certainty of using a correct answer. The rewards are embedded in specific scenarios. In Cell Biology and Anatomy and Physiology 1, the scenario involves the prevention of mutation in cell lines. In Microbiology, the scenario is thwarting an invasion by an alien microbe. The rewards include ATP (a form of energy currency), immune cells and mutation resistance.

The purpose of this paper is to share the results from the use of a DGBL resource aimed at supporting the recall of foundation knowledge and the transfer of that knowledge to similar learning constructs. A pilot study was conducted in 2008 in a first year, second semester unit and forms part of a longitudinal study. This resource is currently being trialled and further developed in the School of HLS at UTas. It is hypothesised that this DGBL resource can enable first year students to revise, apply and extend their knowledge into new domains.

Method

Questionnaire

A hard copy questionnaire, containing both closed and open ended questions, was used to survey the use of the game by HLS students enrolled in Anatomy and Physiology 1. Of the 25 questions in the survey, the results of eight closed and two open questions are presented and discussed. Ethics approval for this questionnaire was granted by the Tasmanian Health and Medical Human Research Ethics Committee (application number HOO10216).

Introduction of the game to the students

Students in Anatomy and Physiology 1 were introduced to the game in dedicated computer laboratory sessions in the second week of semester two, 2008. They comprised 160 students (79 males, 81 females) enrolled in the first year of a UTas undergraduate degree in the Faculty of Health Science, Faculty of Education, Faculty of Business or Faculty of Science, Engineering and Technology. All students had completed a Cell Biology unit at UTas in semester one of the first year of their undergraduate degree.

Study sample

First year students enrolled in Anatomy and Physiology 1 were asked to complete a questionnaire during tutorial time in the thirteenth week of semester two, 2008. Students gave their informed consent and all responses were anonymous. The students were a varied cohort, representing the five degree courses offered by HLS as well as various other courses offered by other Faculties within UTas. The student cohort comprised a mixture of Grade 12 school leavers, mature aged students and students from interstate and overseas. The age range was 18 to 64 years with an average age of 21 years. The widest range was in the "Other" category (19 – 64 years), although there were only eight students in this category. The mean age for all, except the "Other" category, was very similar, between 19 and 21 years.

Data collection

The questionnaire comprised 25 questions, which were both closed and open ended. The questions were designed to obtain a variety of information: general demographic data; general computer use; frequency of game access; opinion regarding the use of a digital game as a learning tool; perceptions of knowledge recall from Cell Biology; and perception of transfer of learning across three core first year modules, Cell Biology, Anatomy and Physiology 1, and Microbiology. The 10 specific questions used to gather responses for this pilot study are displayed in Table 1.

Table 1. Questions Analysed in this Study[a]

Question 1	What degree are you currently enrolled in? E3J M3G M3H M3L M3P M3Q M3R Other
Question 2	Are you male or female? Male Female
Question 4	Did you revisit the game? If so how many times? No 1-2 3-5 >5
Question 7	Did you enjoy playing the game? Yes No Unsure
Question 13	Do you think that the online game has helped you to recall cell biology knowledge? Yes No Unsure
Question 14	Now that you have played the game, can you see content links between cell biology and anatomy and physiology and/or microbiology? Yes No Unsure
Question 20	What did you like most about the game?
Question 21	What did you like least about the game?
Question 24	Do you enjoy playing computer games outside university study? Yes No

[a] The full questionnaire comprises 25 questions.

Students' perceptions of knowledge recall and transfer of learning were obtained via guided, closed questions within the questionnaire (Table 1). Transfer of learning was not quantitatively measured because controversy remains regarding the methodology used to gather such information, and in fact, about what parameters are actually being measured (Barnett & Ceci, 2002; De Corte, 2007; Lobato, 2006; Rebello et al, 2007).

As the questionnaire response rate was small, login data sourced from the game itself was used to validate the representative nature of the questionnaire responses. This information was not gathered directly from students, did not identify students and was electronically sourced.

Analysis

Results from this pilot study were evaluated using a qualitative research methodology including descriptive statistics and phenomenology. Data regarding gender, degree and login statistics were collated according to commonality of response and presented as rudimentary summations about the sample cohort and their respective responses. Some of the interpretations are subjective in nature, particularly those based around the open-ended questions. Whilst phenomenology usually relies on in-depth interviews and responses, it also uses the experience of participants and derives theoretical propositions from their narrative perceptions (Hansen, 2006). The use of inferential statistical methodology is not appropriate with the sample number, the nature of the questions and the fact that the questions used form part of the larger interrelated questionnaire bank in the longitudinal study (Trusted, 1979).

Results and Discussion

This pilot study evaluated results from 50 respondents. Demographic parameters addressed included age, gender, undergraduate degree and tertiary entrance ranking (TER) as shown in Table 2. The overall mean age of the total cohort (160 students) was 21 years. The results suggest that the game effectively targeted the ‘digital natives’ (Van Eck, 2006c).

Table 2. Student cohort grouped by degree, gender, age and Tertiary Entrance Rank

Degree	Students n (male/female)	Age mean (range)	TER mean (range)
B. Human Movement	63 (25/38)	21 (18-43)	66.2 (40.0-89.8)
B. Biomedical Science	24 (11/13)	20 (18-27)	82.0 (62.0-94.0)
B. Health Science	36 (14/22)	20 (18-32)	77.9 (61.0-94.0)
B. Environmental Health	7 (2/5)	19 (18-20)	89.3 (83.4-97.8)
B. Exercise Science	22 (12/10)	19.5 (19-22)	86.2 (65.5-95.8)
Other	8 (2/6)	30 (19-64)	NA
Total	**160 (79/81)**	**21**	**75.4**

Student feedback on the game

One of the aspects of this pilot study was to determine if the students themselves could identify whether or not the game assisted them with foundation knowledge recall and making links between unit material and concepts. Results of the closed questions (questions 13 & 14) revealed that a majority (77%) of the respondents recognised that the game had improved their ability to recall foundation knowledge and to use it in a related context. The directed nature of the questions did not seem to influence the students’ responses because answers to the open ended question about what respondents most liked about the game (question 20), supported their answers to questions 13 and 14. For example, respondent no. 34 agreed the game had helped with recall and making the links between units and commented the game was "More than just regurgitating information". Respondent no.3 on the other hand, thought the game helped make the links between units but didn’t help with content recall. These answers corresponded with his opinion that the game "helps relate cell bio to anat & phys (sic)". A few respondents who thought the game useful for Cell Biology content recall, were either unsure if it helped make content links or thought that it didn't. These respondents all commented that the game helped with revision (respondents 2, 28, 48), or to recall Cell Biology content (respondents 28, 35). At present, the conventional measure of transfer of learning, is the students' ability to be successful in their assessments and ultimately to graduate from university.

Student learning outcomes

Since the completion of the pilot study, preliminary analysis of the end of semester theory examination results from 2008 suggest that respondents' knowledge recall and transfer of learning in Anatomy and Physiology 1 has increased. In 2008, the average theory exam result was 53.1% compared to 48.3% in 2007. This was also the first year where an average theory exam result of above 50% was recorded for this unit. The theory exam contains both MCQ and Short Answer questions (SA). In comparing MCQ and SA sections; in 2007, MCQ average was 23/40 compared to 25.3/40 in 2008 and SA average was 59.4/125 in 2007 compared to 62.3/125 in 2008. These increases in students' examination scores also need to be considered in the context of this specific student cohort and any other pedagogical methodologies and platforms changed within the unit, such as the incorporation of Peer Assisted Study Sessions (PASS), which were also introduced into the unit in 2008. Further analysis of the student cohort performance still needs to be compared across all first year units to determine if there are other factors involved in the improvement of their learning outcomes

Whether or not respondents played other computer games did not seem to influence their enjoyment of this game. In fact, 90% of respondents indicated that they enjoyed the game even though little more than half normally played other computer games. This seemed to be reflected by the gender of the individual (Figure 2) as male respondents were fairly consistent about liking the game and enjoying playing other computer games. The female respondents however, admitted to enjoying the game to a greater degree than would be expected, considering the very small proportion who normally played other computer games.

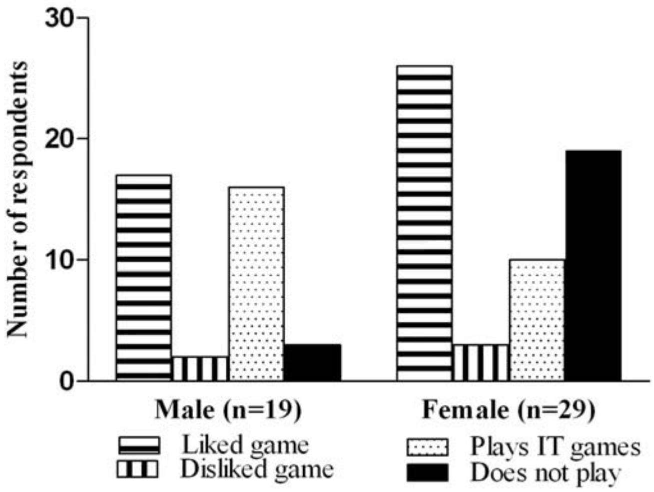

Figure 2. Student engagement with the game by gender

These results suggest the format of the game was such that it not only maintained the interest of habitual computer game users (mainly male in this instance) but succeeded in capturing the interest of those students (mainly female in this study) less inclined to engage in game playing. Gender is an issue in DGBL, as to whether digital games are a 'boy toy' or, indeed, if females will use them to the same degree (Prensky, 2001b). In addressing the issue of whether males and females may prefer differently styled games, it is suggested that whilst some females might prefer 'interaction' rather than 'action', that fundamentally, 'an exciting game is an exciting game', and gender is not an issue if the games are engaging and enjoyable (Prensky, 2001b).

Outcomes from the study and future directions

In this pilot study, the outcomes which support student use of a game format include emotional engagement, challenge and a feedback scaffolding system. The results of this pilot study, we believe, contribute significantly to the body of literature about the use of digital game resources for transfer and application of foundation knowledge, particularly at the level of the first year tertiary experience. The results suggest that our game has succeeded in engaging both 'digital natives' and those new to game technology, enabling them to acquire and transfer knowledge with positive learning outcomes. Accessibility of the game was not an issue with any of the respondents.

Currently the game supports teaching and learning in three first year units (Cell Biology, Anatomy and Physiology 1, Microbiology) which are common to a number of HLS-based undergraduate degrees. Development of the game to include support for three additional units is currently underway, with funding being sought to develop this. It is envisaged that the game will be developed sequentially to include modules which support and link second and third year undergraduate units in the Faculties of Health Science and Education. It also has the potential to be expanded into a generic game based tool for interdisciplinary use across faculties. However, Van Eck (2006c, p.18), cautions against arguing that "*all* games are good for *all* learners and for *all* learning outcomes". He emphasises that research is needed into understanding "why DGBL is engaging and effective" and the importance of taking a realistic direction for "when, with whom, and under what conditions", digital games can be successfully incorporated into "the learning process to maximise learning potential". In addition, Krotoski (2005) believes that whilst today's students are accepting digital games as a powerful learning tool, it may be a challenge to convince the educators who do not yet embrace this technology.

Conclusion

Whilst DGBL resources can be shown to be effective and enjoyable tools for engaging students with core material and with helping students recall knowledge, there is not wide consensus in defining the mechanisms by which this occurs. Ultimately, the benefit to the students, in terms of the progressive transfer of foundation knowledge between units, and its application in more complex situated contexts, is the aim of all higher education institutions. Based on the results of our pilot study which used DGBL resources in first year units in HLS, there are indications of positive outcomes in students' recall, application and transfer of knowledge. A digital game based resource, which fulfils these requirements by engaging and motivating students, will be a valid and valuable tool in the portfolio of teaching and learning resources, particularly at the first year level.

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