Professor to Producer of eBooks with computer games

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Abstract: A professor describes his experiences directing and producing a science fiction novel, in eBook format with computer games, featuring solar system science content, for sixth graders. The embedded computer games were designed to both move the plot forward and act as stealth assessments of comprehension and science content. The idea of this project emerged from a needs analysis of a 6th grade science teacher and science class from a private Christian school. The teacher suggested a strong need for better materials to teach highly spatial solar system content, including phases of the moon, eclipses, tilt of the earth relative to its orbit as the cause of seasons, etc. Our research group decided to create a novel that would be an exemplary piece of content, and an exemplar of web-based eBook with computer games to teach science and language arts content.

eBooks plus computer games: A new format and its rationale

For today's children, the dominant storytelling media are computer games, video, TV, web-pages and texting (Fourie, 2008; Ryan, 2004). However reading skill is, and will continue in the future, to be vital to children's education and careers. Independent reading is an important factor in reading skill (Mol & Bus, 2011). Across western, industrialized countries, children's recreational reading is declining (OECD, 2011). The percentage of students reading for enjoyment daily dropped in the majority of Organization for Economic Co-operation and Development (OECD) countries between 2000 and 2009 (OECD, 2011).

Electronic media are converging. Text, audio, video and computer games combine on webpages and hand-held devices. With eBooks crowding out hardcopy books, eBooks and computer games will converge. Early evidence includes multimedia books for emerging K-1 readers (Smeets & Bus, in press). However, for sixth graders, a group who clearly needs such a convergent media to address reading problems, there is no such product.

Our research group invented a medium that combines books with computer games, in order to revive adolescent interest in books, scaffold learning, provide stealth assessment and tracking for teachers. In this new form of book, called IMapBooks (short for Interactive Map Books), each chapter of text is followed by a computer game that stealth assesses comprehension of the last section of text.

The IMapBook software suite contains: (1) IMapBook Reader, a web-based eReader for students to read/play eBooks plus computer games, including bookcase and achievement badges, (2) Authoring System, for laypersons to input books and computer games into the system, and (3) Administrations System including a system to register new users, and reports from the database, to provide teachers and parents reports on book reader responses and who has registered and when. The IMapBook system is designed both as an eBook/computer game system and a suite of tools for research.

There are three types of IMapBook games: (1) retroactive games, which stealth assess comprehension of the previous chapter, (2) progressive games, where gameplay moves the story forward, and (3) predictive games, where readers hypothesize upcoming possible storylines.

Games in multimedia books can result in poorer comprehension and retention if they are too appealing and distract from the book (Kooy-Hofland, & Bus, in press). Thus the games in IMapBooks are designed to avoid overwhelming and distracting from the reading, but must rather to complement the reading. For instance one type of games is *inference games*, which include a clickable lexicon of words which the player clicks on to produce a short sentence, or inference about content from the previous chapter of text just read. There are also hotspot games, and drag and drop games, both of which are also well suited for the reader to visualize what they have just read in the story.

The professor has conducted six studies yielding many important results, including: (1) fifth graders comprehended and retained spatial information from stories, such as settings, characters movement and locations of objects, significantly better when reading books with computer games, versus traditional books with maps (Smith, 2012) and (2) Chinese undergraduates studying English as a Foreign Language (EFL) learned significantly more new vocabulary with web-based text and computer games than in a control condition with their usual study method,

hardcopy text, lists of words and multiple choice questions) (Smith, et. al., in press).

Theoretical basis

The IMapBook concept is to embed in text narratives computer games that support reading comprehension through design principles motivated by the psychology of reading, specifically through supporting readers' situation models and inferencing which are described next.

High-level reading comprehension involves three cognitive representations: surface code, textbase, and situation model (van Dijk & Kintsch, 1983; Graesser, Mills & Zwaan, 1997). The surface code is the verbatim text. The textbase is the set of logical propositions explicitly in the text, without further inferences. The situation model is the "cognitive representation of the events, actions, persons, and the situation, [e.g., what] a text is about" (van Dijk & Kintsch, 1983, p.11-12).

The situation model is a mental model of the story people update to reflect changes from new events from each sentence. It is the joy of reading an exciting book, the escapist "mental leap into imagined worlds" (Zwaan, 1999, p. 15). The situation model has five dimensions: character(s), goals of characters, causal (how one event changes the trajectory of the story – the house floods, the family moves in with relatives), temporal (flash-forwards and flashbacks), and spatial (where in the setting events happen) (Zwaan, Langston, and Graesser, 1995; Zwaan et al., 1998).

To go from textbase (explicit logical propositions in the text) to situation model, readers fill gaps by inferencing, i.e, using "two or more pieces of information from a text to infer a third piece of information" (Kispal, 2008, p2). Information sources include: a) the text, b) readers' knowledge structures, such as schemata (e.g., knowing that wolves are dangerous is a vital schema in Little Red Riding Hood), and c) the context of the text (e.g., the author, reader, setting and the reading task).

Flashback - history of the project

Since 2007, my IMapBook research group, in the Instructional Technology Program, Dept. of Secondary Education, College of Education, U. of S. Florida, has researched eBooks with computer games. In a technology called IMapBooks (patent pending), chapters of text alternate with computer games. Each chapter of text ends in a computer game that can only be won with accurate reading of the previous chapter and inferencing (Graesser, et. al., 1994). The reader has access to current and previous chapters, but only gains access to the next chapter on wining the game. IMapBooks are backwardly compatible with all narrative books. All books can be converted to IMapBooks.

With the $5,000 of generous internal funding from USF, and the creative efforts of masters and PhD students working in a three-credit course, the professor developed (Prototype Game Research), our group has accomplished a lot. We have submitted a patent, created prototypes of books with computer games, first with pen-top computers and microdot paper, and more recently with Web-based eBooks and computer games, using Html5, xml, Javascript, and PHP. We have published papers in peer-reviewed journals (Smith, 2012; Smith, et al., in press, Smith, Majchrzak, Hayes, & Drobisz, 2011) and in peer-reviewed conference proceedings (Smith & Olkun, 2011).

During this evolution, we learned a number of things: (a) design games so that comprehension of text is required to solve them, not exploratory play without reading the text, (b) approximately 1,000 words of text per each game, based on research, (c) how the games can be used to emphasize different aspects of text (and help readers to better learn & retain), i.e., 5th graders learning spatial dimension of situation models (PICTS) and college EFL students learning new vocabulary

Structure of the research and development group

All work on eBooks with computer games is conducted within a graduate course in instructional technology called *Prototype Game Research*, developed by the director/professor. Each semester there is a new group of students, with a different set of skills and attitudes. One semester, the class has a lot of designers and one graphic artist; another semester a number of programmers, but few designers and no graphic artist. The skill gaps are filled in by alumni of *Prototype Game Research*, volunteering in their spare time. For new students, there is always a learning curve of a three to four weeks as the students come up to speed on understanding eBooks with computer games, the design process and how to use the software suite. At the beginning of the semester, we set goals based on current products and research studies. Prototype Game Research meets once a week. Students get individual assignments related to the current projects, and then the following week report on their progress on the assignments.

There is great esprit de corps in the class because students realize they are not working on canned class assignments, but are working on something real. The students also realize that they are, at the extreme cutting edge, working on something no one else in the world is working on, web-based eBooks with computer games. Each graduate student finds their niche in the group, according to their talents. There is a saying that "once in Prototype Game Research always in Prototype Game Research." Many students continue contributing the group long after the semester of credit is over. All alumni of the class know they can count on the professor and IMapBook family to help them with their careers with recommendations or other supports. But of course such an in flux work force presents many management challenges. The professor directing the group has had to wear many hats: teacher, writer, creative-director, and above liaison to and manager of skilled people from a variety of disciplines: designers, programmers, artists, artists and educators.

Writing a science fiction novel with computer games

After some small prototypes, research studies and peer-reviewed publications, our research group decided we needed one larger piece of exemplary content, an original novel in IMapBook format, to market and show to potential investors. For broad appeal, we wanted to develop an eBook novel that could work both for science and language arts, for sixth graders, our target audience. We also decided that the product must be an exciting and compelling novel for sixth graders. Educational games often are not compelling games, because the education content gets in the way of the games. Similarly, if kids don't want to read the story, no amount of games and educational content will save it. Therefore, a major priority was that the games and education would not get in the way of the novel. Rather, the games and educational content should be "one" with an exciting, compelling novel that sixth graders would happily read and play.

As our IMapBook group is hosted in an Instructional Technology program, with most of the researchers being Instructional Technology Master's students, we used the ADDIE instructional design model to develop this eBook novel with computer games. The ADDIE model is a common instructional design model, where the acronym stands for different sequential phases: Analysis, Design, Development, Implementation and Evaluation (ADDIE).

During Analysis phase, we conducted a needs analysis with a 6th grade teacher and her sixth grade class, in a private religious school, call it Hoffner Christian Academy. We chose to work with this private religious school because it is extremely difficult to get quick Internal Research Board (IRB) approval to work in public schools. Even when just providing new learning materials to a public school, principals will often seek an OK from the highest level of their county district department of education. Given the emphasis on standardized testing, and the focus on curriculum to support performance on standardized testing, it is difficult to get teachers in public schools fit in time for experimental supplementary materials not proven to increase test scores. In fact, as an educational researcher, the professor often feels that he is assumed to be guilty, until proven innocent. With the miracle of the internet, the professor has often found it easier to circumvent IRB and county school district approval by conducting research in other countries, without such aggressive IRB, such as Turkey, Finland and China. In any case the choice of a religious school dovetailed with our proposed market, home schooling parents, who often keep their children at home for religious reasons.

Four students in the research group conducted a Front End Analysis, including: (a) interviewed the teacher of Hoffner Christian Academy's 6th grade science classes to find out her suggestions for developing the CBT content, (b) collected documents related to content (ex. textbook, lesson plans, and assessment items, (c) administered a pretest to students to see what they already know about the content, (d) administered a survey to the target audience (students) to find out what they like/dislike about the solar system, computer instruction. Based on the FEA Design Implications, the product should: (a) be designed in 30-minute modules to accommodate the time allotted for the students to use the computer lab, (b) incorporate games, as 72% of students reported games as their favorite computer activity, and (c) he content should be developed from the school's textbook and address the information contained in the pretest.

During informal interviews, the sixth grade teacher, suggested that certain solar system content with spatial content was challenging for her students: (a) seasons caused by tilt, of the axis of the earth's rotation, relative to Earth's orbital path, (b) lunar phases, and (c) eclipses. One of the graduate students in our group assured us (and backed it up with common core standards) that seasons, lunar phases and eclipses, were also part of 6th grade public school curriculum.

The sixth grade teacher gave me a copy of their science textbook, along with tests, quizzes and worksheets for various units. The professor scanned the solar system chapter, and distributed it to the graduate students in his research group. The textbook presented science content in an engaging way, but for a few in the research group who were not religious, certain passages in the science textbook were a culture shock:

Copernicus believed that the Sun was the center of the universe and that the planets revolved around the Sun. For this startling publication, Copernicus was considered a heretic. Only after many years did scientists prove that the Sun is indeed the center of our solar system. God's orderly pattern for the universe allows man to prove mathematically ideas that he cannot prove experimentally (Sixth Grade Science Textbook, used in Christian School).

So that our IMapBook would be amenable to both religious and secular schools, we decided to focus on science content, but not to explicitly mention religious content or use any religious slant.

As part of the Design phase of the ADDIE model, we brainstormed different plot ideas, and characters, that would fit well with the solar system content. We employed "rules for brainstorming" that the professor originally heard in a workshop at GLS in 2010: (1) Quantity over quality (not just two, as many as you can), (2) No judging (especially no self-judging), (3) Go wild, (4) No "but"s just "and"s, (5) Combine ideas, (6) Get visual (sketches). At group meetings, researchers for five minutes individually wrote down, on "post it," notes as many plot ideas as possible. We then compiled favorite ideas and wrote them on a whiteboard to discuss. We also generated plot ideas at home and brought them to the meetings. All ideas were evaluated along several criteria: (1) how integral solar system content was to the plot, and (2) the potential of the plot for a compelling scenes, and a compelling story that sixth graders would enjoy reading.

Finally, we decided that the setting should be aboard a spacecraft within the solar system. We decided that the main characters should be two 11 year olds, a boy (Adam) and a girl (Shiranna), to appeal to both genders. After several weeks, considering dozens of different plot ideas, we selected this plot: Two eleven-year-old children on a spacecraft in the solar system, awake from hibernation to find they are alone. All the adults on the spacecraft are still in hibernation, and cannot be awakened. The two 6th graders are then confronted with earth-shattering problems that relate to solar science content.

One of the students in our research group, John, has a Bachelor's in Physics and Astronomy. John became our Subject Matter Expert, or as posh Instructional Designers casually say, our "SME." John elaborated the plot into a more detailed scenario that might fit physics and solar system content as a causative element in the plot. Adam and Shiranna, on a shuttle from Earth to Venus, awake from hibernation to find that the spacecraft has been damaged through a collision with a small asteroid. The damage has made it impossible to awaken the adults. Adam and Shiranna soon a receive a message from Earth, saying that a planetoid sized asteroid is on its way into the solar system, on a course close enough that its gravitational pull will change the tilt of the earth, potentially catastrophically changing the Earth's seasons. Adam and Shiranna, being the closest humans to the asteroid, are called on to find a solution. The director of the research group elaborated the plot outline into a long short story, including brief ideas for computer games. Designers in the research group elaborated on these game ideas, with written game descriptions and storyboards. With just two characters, Adam and Shiranna, and the paraphernalia of the spacecraft, the introduction of science content into the games felt very artificial. The director of the project suggested we add a third character, a small cuddly robot commercially, designed for companionship and recreation, called Cheeky. Since Cheeky had formal knowledge, but little common sense social knowledge, it felt plausible for Cheeky to introduce science content or ask scientific questions. Cheeky essentially served the role of pedagogical agent within the games, as well as comic foil in the story. The director also came up with a title for the story, Weightless, which he just to succinctly represent the experience in space, and also to symbolize the experience of two "tweeners" called on to save the world without the help of adults. The lack of adult guidance was as disorienting as the lack of gravity.

As the start of the ADDIE phase "Development," we entered the short story version of Weightless, interspersed with two sample games, into the IMapBook eReader system. The sixth grade class at Hoffner Christian Academy read the eBook and played the two sample computer games. The students felt it was an exciting plot ("Hey, what happens next?") and the games were a fun way to approach solar system content. But the sixth graders said, "This isn't a real book." After a focus group discussion, it came out that it wasn't a real book, not because was computer-based or had computer games, but because the writing was not professional. Whatever qualities the students were used to in commercially published books for sixth graders, obviously a tenured professor of instructional technology, however skilled in academic writing, could not deliver the goods. We hired a young ghostwriter, who was our SME's niece, to write the novel from our scenario. The young ghostwriter, trying to break into the publishing business, was writing two other books for the same sixth grade audience, so it seemed like Kismet, when our SME, Bill, suggested the idea. Our research group read samples of his writing, and decided he had to skills for fiction writing for this audience.

Now we need a real novel

The professor remembers in June of 2012, while attending the GLS conference, standing on the memorial union terrace looking out at Lake Mendota, talking into his cell phone negotiating with the young ghost writer, trying to sound like a tough businessman while gazing out at the ineffable, beautiful blue of the wind-swept waves. In fact, the young writer, all of 25 years old, struck a hard bargain, claiming, "for any less money, I might as well get a summer job slinging hamburgers." The professor had to provide him with a $2,000 down payment to get him to started writing, with the balance due on completion of the novel. However, the money has been well spent, producing a compelling novel. Based on the advice of my lawyer friend, the professor downloaded a copyright agreement from Legal Zoom, and customized it to our needs. The writer worked on Weightless for months during contract discussions, before the professor could actually get the writer to sign the contract. Somewhere along the way, the professor realized he had become a producer.

From July 2012 to February, the ghostwriter, the writer, and the project director and worked as co-authors. The writer wrote installments and emailed them to me. The professor read and provided minor feedback. Mostly it was heady exhilaration to read the scenario, the professor had helped dream up, now in novel form. The writer could cast the rough scenario into vividly imagined real life details and put them into text narrative in way that was compelling and left me constantly wondering what would happen next. The characters seemed like real people, in trouble, who the professor cared about and the professor wanted to know what would happen next to them next, even though, ironically, the professor already roughly knew what would happen since the professor had helped to write the plot. All his life the professor had the fantasy of one day writing the great American novel. With the years of publishing peer-reviewed academic paper, the professor thought he could easily write a novel. Now confronted with the magical process how a real fiction writer creates a novel, the professor realized that his literary dream was pure delusion.

Occasionally, the writer and the professor had some disagreements about structural issues in the novel. A common problem was tension between 100% scientific accuracy (which the professor felt was necessary for the eBook to be credible as science content for schools) and demands of working compelling fiction. The writer informed him that all science fiction has what he youthfully termed "What the F___ moments" where the reader is asked to accept large gaps in logic or believability in the interest of maintaining a compelling narrative flow. As long as the story is compelling and the "What the F___ moments" are not frequent, the reader is happy to overlook the "What the F___ moments."

The professor had two major dis-agreements with the writer. The first was over a point in the story that seemed scientifically unrealistic. We resolved that by consulting via email with the head of the astronomy department at the University of Amsterdam. The second problem was when the writer, in an effort to finish the novel quickly before shifting his attention to law application deadlines, wrote an ending that was rushed and superficial. We resolved that by negotiating that he would first apply to law schools, and then after that write a more developed ending.

Process for designing and creating computer games to go with the novel

With a critical mass of the novel in place, working with the graduate students to designed and create the games was a priority. The writer wrote brief game descriptions at the end of each chapter. During the July and August of 2012, and later in the Fall of 2012, the professor worked a team of graduate students to design the games. The professor would assign the brief description of an idea for a game to one or two students, who would then flesh out the game idea into a more elaborate text description and a storyboard. The team would often suggest revisions. When the game description was approved, the game designer would write a description of the graphics needed for the game, to be sent off to the artist, who an alumni of the course. The artist would then supply rough conceptual sketches. When the group approved, the artist would produce final renderings.

The games in the IMapBook system are defined in a simple xml language, which is then interpreted by the eReader to produce for the game player the game interaction. This system avoids the problem of having to program each new game from scratch. During the summer, the designers wrote xml with a text processor program to create games. The problem was that the xml syntax, while not requiring a formal programming background, was still exacting and required a lot of patience.

At the end of the summer of 2012, we did a formative evaluation with one fourth of the eBook with computer games. Eight students who were struggling readers (transitioning from sixth to seventh grade) in a prep school summer course, read one fourth of the book and played the games. The students took an online questionnaire answering twelve open-ended questions, including about the story (what they liked and what they thought should be improved), about the games (what they liked and what should be improved), and questions about the user inter-

face. The eight students also took part in a focus group. Overwhelmingly, the students found the novel compelling and wanted to read more. They definitely liked having the games in the book, but felt the games could be improved to be more game-like. Based on this formative feedback, the novel was edited in minor ways to improve clarity. The research group also decided that a greater range of types of games was needed.

During the end of the summer, one of the programmers in our research group wrote an authoring tool that allowed non-technical designers to more easily design and create games. While designing games in the Fall of 2012 using the alpha authoring system, a challenge has been that the authoring system and the xml language that it generates are well-suited to creating certain types of games and less suited to creating other types of games. In some cases, the designers really struggled to create the game ideas outlined by the ghostwriter and the director of the project. Because of this, the programmer of the authoring system was asked to create revisions to the authoring system to add other types of games (for instance drag and drop games) that would make game design easier. Another challenge was that our designers were using the authoring system in alpha form before it was debugged. They therefore often found bugs, reported them to the programmer, who then fixed them. This slowed the development process. However these logistic problem are typical of the Development phase of the ADDIE model.

Current status

As of this writing in February of 2013, the novel is complete. The ending is by far the strongest section of the novel. There are computer games for about half the novel. However, the professor feels that some of the games need to be revised, by converting them to drag and drop games. Further, a lot of the chapters with their games exist as separate files, and need to be integrated into one book. In the spring semester, the group is also revising the look and feel of the eReader and creating a beta version of the authoring system. As Implementation and Evaluation phases in the ADDIE model, the group conducted formative evaluation of 60% of the book with games in April of 2013, in a public school with two sixth grade language arts classes, and two science classes. Almost all of the students found the story engrossing, and wanted to read more. They also like the overall concept of web-based books with games. They did feel that the games needed refinement. Intriguingly, three students with learning disabilities (problems with concentration) particularly took to the eBook with games, persevering for a long time, and tutoring actually their normally higher achieving peers on the games.

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