This Issue:

From the Editor
Leslie Moller, Senior Editor

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About

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The purpose of this journal is to bridge the gap between theory and practice by providing reflective scholar-practitioners a means for publishing articles related the field of Instructional Design.

JAID’s goals are to encourage and nurture the development of the reflective practitioner as well as collaborations between academics and practitioners as a means of disseminating and developing new ideas in instructional design. The resulting articles should inform both the study and practice of instructional design.

JAID is an online open-access journal and is offered without cost to users.

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For questions contact Don Robison at drobi036@odu.edu
Hello Friends and Readers

In 2010, Gary Morrison, one of our top Scholars of Instructional Design, proposed to the board of AECT a new journal dedicated to the scholar-practitioner and thus the Journal of Applied Instructional Design was born. The purpose of the journal was:

The purpose of this journal is to bridge the gap between theory and practice by providing reflective practitioners a means for publishing articles related to the field. The proposed journal will establish and maintain a scholarly standard with the appropriate rigor for articles based on design and development projects. Articles might include evaluation reports (summative and formative), lessons learned, design and development approaches, as well as applied research. The articles will be based on design and development projects as opposed to pure research projects and focus on lessons learned and how to improve the instructional design process. Rigor will be established through articles grounded in research and theory.

It was an honor to be asked to serve as the founding editor for 2 years, which has become 4 years. But I think it is time for me to step down and I believe that our new editor will continue and even likely improve JAID.

Associate Editor Wilhelmina C. Savenye, Ph.D will take over the role of Editor with the publication of this issue. Since the start of the journal Willie has been part of every issue and I have complete confidence that the journal will steadily improve under her leadership.

Putting out a journal like this takes more than one or two people. Don Robison, the Production Editor, has been an essential part of putting ideas into the publication and I am especially proud of the cover and article that he was solely responsible for on Malala Yousafzai.

Douglas Harvey, our other associate Editor has been a tremendous help in reviewing articles, giving feedback to authors and generally being there for whatever help I needed.

I owe deep thanks to Associate Editor Ben Erlandson who serves as our copy editor.

Although she was not given a long time or many opportunities, mostly my fault, Alexandra Salas served as blog and I hope the forthcoming issues will offer more interactive blogs. I am especially proud of Alexas since she recently completed her Ph.D. and I was fortunate to be her chair.

Although this would go on forever, a group thanks to all our reviewers and the journal’s Editorial Board.

All these people helped us to produce the journal and the results were very good. We had over 8,000 unique readers many of them repeat readers representing over 2,300 unique cities in 118 different countries.

As a long time scholar-practitioner I think this journal serves an important need. Although ETRD, and our other journals serve key function in advancing our field, the scholar-practitioner brings a different perspective and contribution than would be impossible for traditional researchers. In my 20 years of being a practitioner every ID project was also a learning experience for me. Even my more traditional research publication began as the results of being a practitioner. One never knows where ideas will take a person.

On a personal note, I am deeply grateful to the journal and AECT for giving me this opportunity. It allowed me to read a lot of great articles, work with some fantastic people, and provided me a sense of giving back to AECT and the Instructional Design community.

With a nod to Roy Rodgers, “Happy Trails to you”

Leslie Moller Ph.D.
Editor, Journal of Applied Instructional Design
Les Moller has served as the Senior Editor for the *Journal of Applied Instructional Design* since its inception four years ago. He is stepping down to allow others the chance to grow and contribute.

Thank you, Les, for your hard work and leadership. We wish you all the very best!

*The Staff of JAID*

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- Applications of new and emerging technologies within learning contexts
- Trends in design-based research
- Designing learning environments
- Applications of learning analytics
- MOOCs & LOOCs
- Rigorous applications of research methods
- Influence of culture on learning/learning culture

*See you in Jacksonville!*
Since at least the 1980s, educators have formally explored the use of video games as instruments of teaching and learning (Malone, 1981). Despite interest in this technology, recreational video games have often been viewed with skepticism in academic settings, with detractors claiming them to be frivolous forms of entertainment (Van Eck, 2006). As educational video games (EVGs) grow in popularity, the discussion has shifted from a focus on the purpose of games towards an understanding of how game design intentionally influences behavior and learning.

What makes well-designed EVGs potentially effective teaching tools is the ability to place learning within a meaningful context. Video games provide a world in which players can develop and practice new skills in a designed immersive medium. A well-designed game motivates players to persist in the face of calibrated challenges. In EVGs, this in-game motivation acts as a catalyst in learning and encourages students to further their understanding with every session of play (Devlin, 2011). With a growing interest in EVGs, educators see an opportunity to help students master challenging material in an enjoyable learning atmosphere (Gee, 2003).
Video games are now used to teach difficult concepts including, “people management, difficult to learn software, complex financial products and intricate social interactions” (Prensky “Digital Game” 2001, p.9). One study conducted with high school students divided a class into two groups to teach computer memory concepts. Both groups had the same learning objectives and material but one group used gaming as the instructional technology. The students in the gaming group exhibited significantly greater knowledge of the material as well as viewed the application more positively than the control group (Papastergiou, 2009).

Given that EVGs have the potential to be powerful learning tools, the challenge becomes designing an engaging game that motivates students in an intentional way. The success of an EVG, therefore, might be evaluated by the ability to incorporate learning objectives into the gaming environment that absorbs students into game play. While the former challenge rests on the ability of educators to translate their material into a gaming format, the latter requires significant input from designers. For professionals from diverse design fields to work together successfully there must be a common language used to communicate the problems they seek to address. By moving in this direction, the likelihood of EVGs that satisfy criteria of success from each field could increase.

Game design patterns can be used as a common language system to effectively communicate educational and game design principles. The term “design pattern” was first introduced by Christopher Alexander to describe a recurring architectural design problem (Alexander, 1977). The term has since been adapted for computer science and game development to describe commonly recurring elements of design (Gamma et al., 1993). According to researchers Björk and Holopainen, “game design patterns describe a part of the interaction possible in games, and together with other patterns they describe the possible game play in a game” (2005, p.4).

Given many types of games for educational and recreational purposes, there are a correspondingly large number of possible design patterns (See Appendix A 1 for design pattern examples; Kinzer et al., 2010). For EVGs, identifying design patterns could help locate synergies between the recreational and learning components in games (Kiili, 2010). When design patterns are organized to refer to one another, they create a “pattern language” (Huynh-Kim-Bang, 2010). Although this pattern language is useful for describing a game, it is incapable of judging the effectiveness of the design. Instead, it can be a useful tool for identifying areas for improvement (Björk & Holopainen, 2005). In the case of the app, the research team identified relevant design patterns, then sorted them into three categories based on the Games for Learning Institute’s game design rubric: technical implementation, educational appropriateness, and fun and enjoyment (Kinzer et al., 2010). Technical implementation addresses the programming and execution of game design patterns. Educational appropriateness assesses the game’s ability to address learning objectives relative to students’ education levels. Fun and enjoyment assesses the game’s ability to entertain and engage students to achieve the educational end-goals. An analysis of the CandyFactory app design patterns, using the Games for Learning Institute rubric, identified areas of strength as well as weaknesses that should be addressed to make the app, as well as similarly designed media, more effective.

The Candy Factory App: Introduction & Purpose

The CandyFactory app, available for download from the Apple iTunes Store, is an EVG designed for the iPad to support middle school students in the conceptualization of fractions. Students work through five game levels that are designed to provoke the development of more and more sophisticated conceptions of fractions. The five levels correspond to the five fraction schemes described in Table 1 (Norton, Wilkins, Evans, Deater-Deckard, Balci, & Chang, 2014; Steffe & Olive, 2010). The goal of app is to work through five levels (or shifts) of a fictional candy factory to earn a promotion. For each level, students race the clock to complete customer orders and earn achievements based on performance.

In level one, students can apply a part-whole fraction scheme—the most basic fraction scheme. Students begin by using visibly partitioned candy pieces to assemble a variety of customer orders. Students can count the number of pieces in the candy tray (n), then select the number of pieces needed to fill a customer order (m), to create the fraction of the whole (m/n). At this level, students work with proper fractions; i.e., the number of pieces in a customer order will never exceed the number of pieces available in the candy tray. Beginning with a simple part-whole relationship (m/n) helps acquaint students with game play before progressing onto more complex relationships.

In level two, students are challenged to develop the partitive unit fraction scheme (PUFS). Students no longer work with visibly partitioned candy. Instead, they must use finger swipes to slice each bar into smaller pieces of equal size. They then select a single piece to create a unit fraction (1/n) that will match the order size. Imagining the whole as a repeated unit fraction helps students transcend the part-whole concept of fractions and begin to understand unit fractions as sizes relative to the whole.

Level three also concerns a generalization of the PUFS—the partitive fraction scheme, which and requires students to produce non-unit proper fractions to complete the customer order. This involves a generali-
zation of the PUFS. Students should begin to conceptualize all proper fractions as sizes relative to the whole, and to conceptualize \(m/n\) as \(m\) copies of the unit fraction \((1/n)\).

Level four relates to the iterative fraction scheme. Students are asked to produce any fraction, including improper fractions (a scenario of \(m/n\) where \(m\) can be greater than \(n\)). Although the logic required to complete orders in level four may appear similar to the partitive fraction scheme introduced in level three, the reasoning involved is qualitatively different. To properly produce the improper fraction, students must coordinate the unit fraction, improper fraction, and the whole within the improper fraction. Students who do not coordinate these three units will often confuse the improper fraction with the whole (Tzur, 1999).

Lastly, level five provokes players to develop a reversible partitive fraction scheme. This final level works in reverse of level four. Upon entering level five, students are informed that a mistake in the factory caused orders to be made a fraction of what the customers wanted. To correct this mistake students are given the fraction (proper or improper) and asked to produce the whole from it. For example, a student could be given a piece that is 7/5 of the whole. The student will need to slice the given piece into 7 parts and make 5 copies of that piece to produce the correct order.

To encourage game play and help assess progress, students receive a performance review at the end of every level (referred to as a shift log) and are awarded trophies based on the speed and accuracy of their work. Additionally, players also receive in-game feedback during each level (or shift). The game’s antagonist, Boss Cog, appears on screen to chastise students when they submit an incorrect order or take too long to complete an order. He also offers praise when students submit correct orders and informs students when their shift is almost over.

To assess whether the game’s design aided in the overall goal of helping students to progress along the five levels of the fraction scheme, a design research team was organized to conduct a full usability analysis of the currently deployed application. The team was comprised of professors and students from the fields of instructional design and technology, the learning sciences, creative technologies, mathematics education, and visual communication. The goal of this study was to identify areas where the game’s design and functionality impeded the underlying educational goals, and provide possible design suggestions to increase the usability of the CandyFactory app.

**Research Methodology**

Three usability studies produced multiple data streams to complete the holistic evaluation of the app. First, task based usability techniques (Abel & Evans, 2014) were applied during internal review, interactive observational techniques of usability analysis were incorporated during the second phase (Millen, 2000), and lastly face-to-face interviewing was completed with classroom teachers. Each data stream provided insight into the usability of the app and collectively revealed, using the Beyer-Holtzblatt (BH) Contextual Design methodology (BH Method), opportunities to increase overall usability.

First the research team conducted the internal task-based usability testing in Fall 2012. Six team members played through the app and documented any issues encountered relating to the user interface, mechanics, and overall game play. Results were organized into six (6) categories: game play, in-game feedback, interface,
narrative, rewards and visual measurement. For each category, issues were identified and interpretations made by the team to reach a consensus as to criticality. Appendix B represents the agreement on critical issues that potentially prevented the game from attaining stated learning goals as well as reduced enjoyment and replayability.

Following the internal game assessment, the research team conducted an on-site interactive observational playtesting study at a local middle school. Research team members conducted moderated one-on-one interviews and interactively observed playtesting with sixteen students (n=16, gender balanced: 8 males, 8 females, randomly selected to participate by their classroom teacher, load balanced: all asked to perform the same task). Prior to participation in the playtesting, the students answered several pretest questions for the moderator regarding their familiarity with the app and their affinity for the game (see Appendix C). Students then began playing the game while the moderator observed their game play and prompted the students with occasional questions regarding the game’s design, objectives and challenges (See Appendix C for both qualitative questions and interactive observational usability task questions). As the students played, researchers noted when students struggled with tasks, became frustrated by game mechanics, or had difficulty understanding game elements. Incorporating the interactive observational usability technique allowed a more passive role in questioning the students resulting in more qualitative data with minimal disruption of normal game play.

Finally, the team conducted face-to-face interviews with six teachers from a local middle school to capture data on the game’s effectiveness as a teaching tool, and other comments regarding the overall design and use of the app (see Appendix D). These teachers have been recruited by the more comprehensive funded research project to incorporate EVGs into the middle school mathematics classroom. These teachers were provided a 2-day introduction to the app, suggestions on how to incorporate the app into lesson plans, and support materials to increase probability of success with adoption.

Once complete, data from all three usability sessions was assimilated into a spreadsheet and analyzed using the BH Method (Holtzblatt & Beyer, 2013), which builds on an original affinity model of analysis created by Jiro Kawakita, commonly referred to as the KJ Method (Kawakita, 1982). Kawakita devised the KJ Method when standard anthropological techniques proved inadequate to analyze the massive amounts of qualitative data he had amassed during research for the Japanese Government. Business researchers and strategists incorporate KJ-Method when they generate affinity diagrams. Essentially the KH Method assists with data analysis by grouping, organizing, and sorting data into reoccurring thematic areas. Once identified, the thematic areas contain subsets and indicators of all usability data collected. Ultimately, feedback from these three data-streams was compiled to identify strengths and weaknesses of the app to gain a better understanding of the target audience, and gather insights to provide design improvement suggestions for future iterations of the app as well as any future EVGs created by the publishing university. These efforts focused on such features of the app as game play, tutorial mode, trophies and bonus money, characters, and game mechanics. Appendix F provides excerpts from the usability report and further detail can be found in Abel and Evans (2014), and Evans, Abel and Musselman (2013). In conclusion, it should be noted that for the purposes reported, the BH Method is one implementation of the original KJ Method, and is adapted for usability testing resulting in a more holistic evaluation of the system being tested. Additionally the BH Method lends itself to rapid generation of descriptions and potential solutions to usability data.

Results

Based on data gathered from the three-phased usability study, the research team created a list of game design patterns that were then grouped into the three categories defined by the Games for Learning Institute rubric (Kinzer et al., 2010). Grouping the design patterns in this way created a pattern language that was used to describe and assess the app’s technical implementation, educational appropriateness, and fun and enjoyment.

Technical Implementation

Given that the assessment of technical implementation is based on the game’s ability to seamlessly integrate design patterns into game play, it is necessary to discuss the game’s mechanics: “methods invoked by agents for interacting in the game world” (Sicart, 2008, p.1). For example, Miguel Sicart describes the 2006 Nintendo game _Orbital_, in which the player flies a small unit around space collecting items, as an exemplar of executing this design pattern type. As the player collects more items the unit grows, and as it increases in size is able to create its own gravitational field. Sicart claims that the game mechanics are attraction/repulsion actions, the gravitational fields of the planets, and even how the player can use gravity to propel the flight (2008).

For the app students were overall able to proficiently navigate through the user interface and were knowledgeable about game settings and features (see Appendix E). Nevertheless, the game research team identified two game mechanics that created difficulties for players and might unintentionally prohibit engagement and
learning.

Redundant icons and actions created confusion and slowed play. To ship an order in the app, the player must first tap a small shipping icon to activate a larger shipping icon. The player must then drag their completed order to this larger icon. The use of redundant shipping icons coupled with the different methods of interaction (tapping and dragging), created confusion. Some players attempted to drag their completed order to the shipping icon, rather than tapping the icon and then dragging their orders. This confusion slowed game play and created unnecessary frustration.

Selected interaction physics greatly slowed game play. A portion of students reported frustration with the swiping mechanic used to separate candy pieces into smaller units. The swipe to cut feature was introduced in the level two. In level one, users could select the number of partitions they wished to make with a button press. The repeated act of swiping slowed some students and many were unsure how to remove unintended swipes, which created confusion and frustration. In some cases students spent an inordinate amount of time methodically swipeing in even increments because they were unaware their partitions would be evenly divided on the next screen. Although the swiping mechanic made the levels more interactive, some students seemed more willing to exchange the less time-consuming button push if it meant having more time to solve problems and earn trophies. Correcting these mechanical issues will help make the app user-friendly and optimize game play.

Educational Appropriateness

In participating middle schools, the app was introduced during class time as a way to complement instruction on fractions. A majority of students participating in the study reported the app helped them learn fractions. Despite a positive assessment from students, the research team used design pattern analysis to locate possible areas for improvement to maximize learning objectives.

Time constraints became counterproductive in higher levels. Although some students attempted to solve levels via trial and error, having a timed component meant only students who had mastered the underlying concepts would be able to earn the highest awards. Having a time constraint encouraged repeated game play as students attempted to improve their scores over previous levels. However, in higher levels, students reported non-constructive frustration relating to an insufficient amount of time to complete tasks. Although students have the option to turn off the clock, this is not necessarily encouraged or allowed in a classroom setting. Alloting students more time for higher levels could encourage students to carefully consider each problem rather than defaulting to trial and error.

In-game feedback became a distraction. When students make a mistake or run low on time Boss Cog animates onto the screen to chastise the player. Although this may be an effective motivator for some students, the animation itself defies the Split Attention Principle, which states that learning is hindered when learners are forced to split their attention between several sources of information (Ayres & Sweller, 2005). In this case, students are trying to understand why Boss Cog is reprimanding them (either for poor performance or to warn them about time) while also trying to complete the next order. In addition to breaking the Split Attention Principle, the placement of Boss Cog is directly over key information necessary for the student to complete the current order.

Post-game feedback did not clearly indicate where students had erred. At the end of each level, a shift log appears to show students their evaluation for each level. The shift log shows their overall performance and how long they took to solve each problem. Teacher feedback indicates the shift log should clearly indicate which orders were completed incorrectly to help students identify areas of improvement. Including the solution to incorrectly filled orders also provides another learning opportunity for the student.

An additional tutorial may be necessary to introduce students to new goals. Game narration helps guide students through the levels of the app and helps establish level expectations. Upon starting a new game, students click through a tutorial that explains the goal of levels one through four. Although level five begins with a narration that sets up the new task, students reported difficulty knowing what was expected in this level. Including a tutorial for level five could help address this issue.

Fun & Enjoyment

The research team identified design patterns that were implemented successfully to help maximize fun and enjoyment:

In-game motivation kept students engaged. Students receive two types of motivation in each level – trophies and bonus money. Trophies are awarded based on three criteria – speed of completion, order accuracy and customer satisfaction. Students reported that they replayed levels in order to collect more trophies. Bonus money was a less effective motivator because students said it was unclear what reward they would earn for the bonus money but many indicated they would be more willing to work for the bonus money if they could exchange it for in-game rewards.

The app incorporates multiple mechanics that allow students to interact with the game space. Learning
materials with interactive components are more likely to engage students than static graphics (Lowe, 2003). The app incorporates three types of dynamic representations: “transformations, in which physical properties of an object are altered, translations, in which objects are moved from one place to another, and transitions, in which objects appear or disappear” (Lowe, 2003). 

Icons helped students quickly adapt to the game interface. Once students complete the pre-game narrative and tutorial, icons and other images are significantly more prevalent than text. Using visualizations over text is particularly useful when a subject is unfamiliar to the learner (Plass et al., 2009). Minimizing the time required to familiarize themselves with the gaming environment allowed students to quickly immerse themselves in game play.

Students enjoyed manipulating game objects. In each level of the app, students were able to manipulate game pieces to assemble customer orders. Customer orders are a fraction, either proper or improper, of the available candy’s size. Manipulating the available pieces helped students develop the underlying skills needed to visualize fractions.

Students felt the overall aesthetic of the app was very polished. Students overwhelmingly responded positively to game graphics including the game interface, characters, colors and candy. Although games can be fun without impressive visuals, students responded enthusiastically to the app imagery.

By assessing the game construction, it was also possible to determine areas for improvement to maximize enjoyment:

Allowing students to modify their game interface could increase engagement. Currently the bonus cash does not relate to any game elements. Nevertheless, when asked what they would buy with their money, the majority of students said they would like to buy more candy. Allowing students to select new candy will give them the ability to customize features of their interface and increase engagement.

Uneven shifts in difficulty between levels created frustration and visibly disrupted the student’s reasoning process. One of the primary goals in educational video game design is to balance the challenge of learning with enjoyment, or rather create “hard fun” (McGonigal, 2011). Games are more engaging when a challenge adjusts along with a player’s experience (Sweetser, 2005). Students were able to translate their knowledge from Level 1 to solve Level 2 tasks with some assurance of success. In Level 2, students are expected to conceptualize unit fractions as sizes relative to a given whole (example: 1/4, 1/6, 1/10), which most did successfully. In order to amass the full collection of trophies, students replayed Level 2 until they had mastered this concept. Level 3 however became disproportionately challenging. Students seemed less capable of applying the concepts developed in Levels 1 and 2. In Level 3, students are required to imagine a unit fraction of the given whole that can be iterated (or copied) in order to produce a non-unit proper fractions – especially difficult examples include 5/9, and 8/9. Failure rates were significantly higher in this level with no students completing Level 3 to the same standard set in previous levels. Most students relied on trial and error, even upon multiple replays. This lapse in performance suggests the increased challenge is too great to be productive for the players. It is likely that imagining 1/7 of a whole is not sufficient for students to visualize the difference between 6/7 and 7/8. Although a certain degree of challenge is necessary to create a fun gaming atmosphere, this leap produces the opposite result. One way to help students overcome this cognitive hurdle is by adding an intermediate level between current Levels 2 and 3, that includes only complements of unit fractions, (n-1)/n (for example, 6/7 or 7/8). In fact, in a separate study of the app’s implementation, researchers found some students independently employing “the complement strategy” to solve tasks at Level 3 (Boyce & Norton, 2012). By focusing students’ attention on the missing piece (e.g., 1/7 as the missing piece between 6/7 and the whole), the new level could help students transition from working with unit fractional customer orders (e.g., 1/7) toward customer orders that involve several iterations of those unit fractions (e.g., 6/7 as six iterations of 1/7).

Incorporating a social component to encourage mild competition could be one way to increase engagement and repeated game play. This could be done by creating a classroom progress board that tracks student achievements in the game.

Despite possible areas for improvement, in student feedback sessions, students were asked how they would rate the game overall on a scale of one to four, with one meaning “not at all” and four meaning “very much.” The average student rating was three. When asked how likely they are to recommend this game to a friend with one being “very unlikely” and four being “very likely,” the average student response was 2.9.

Discussion

The research team discovered that students who participated in this study enjoyed playing the app and felt it helped them understand fractions. Nevertheless, assessing student game play through the lenses of design pattern analysis and usability testing techniques helped identify elements that impeded the learning process.

In the game, to “ship” the order, the player has to press a button and then drag the box towards another button to complete the action. This is a redundant interaction that sometimes causes players confusion.
streamlining this interaction one can increase use and ease frustration while making the game more enjoyable.

When the students were feeling rushed in higher levels (Levels 3 through 5), they would attempt to win via trial-and-error. For example, instead of taking the time to think through the problem presented to them and coming up with an appropriate solution, they would haphazardly try to divide up the candy bar as quickly as possible to try to get it to fit the order. In other cases, they would divide up the candy bar as small as possible to be able to fill the order exactly, but this would cause the player to take more time to fill the order. This method often produced fractions that could be simplified, thus using this method suggests students were having difficulty visualizing the bars as fractions of a whole and were merely aiming to get one image to correspond with another. If more time were given to higher levels, perhaps it would deter this action that defeats the purpose of the game.

Another way to help ease the student into higher levels is to introduce a new, intermediate level to help bridge the gap between Level 2 and the higher levels. As it stands now, it appears that the students are not properly prepared for the higher levels and they have trouble visually measuring the candy into complicated fractions. Providing better tools for visual measurement could help reinforce the partitive relationship and encourage students to methodically work through each problem.

The majority of the students reported feeling comfortable with in-game expectations, but the research team observed that students did not know what to do upon reaching Level 5. Unbeknownst to them, they need to find the reciprocal of the fraction given, which they would not know to do without either guessing or instructor guidance. Offering optional tutorials for each level would allow for students familiarize themselves with each level without slowing game play for those already acquainted with the rules and expectations. For example, for Level 5 designers could incorporate support that guides students to reason that, if the given fraction is 3/5 for example, they need to produce 1/3 of 3/5 (i.e., 1/5) to produce the whole (five iterations of 1/5).

Students found in-game feedback from Boss Cog too distracting. His presence is intended to motivate players, but instead his many appearances distract or confuse players. Boss Cog currently appears to assess orders, denounce players for taking too long on an order, or warn players the shift is about to end. Players were occasionally unsure of what prompted Boss Cog to interrupt their game and had to pause to determine the cause. To minimize confusion and distraction, Boss Cog could either not animate on screen or he could only appear to inform the players of one issue – for instance he could praise or condemn correct and incorrect orders. Removing warnings related to time will allow students to feel motivation to please Boss Cog without constant interruption.

At the end of each level, a shift log appears which details all the orders the player filled. It explains in each order what the correct fraction was and what the player entered. Currently, there is no visual distinction between correct orders and incorrect orders, so a quick glance will not be sufficient to gauge performance. Clearly indicating incorrect orders would be useful to allow the player to identify areas of improvement.

Competition can increase motivation to perform well, thereby creating a social component to the game that encourages a bit of inter-classroom competition. As long as it is done in a way that does not discourage students, it could increase engagement in the game and drive the students to play the game multiple times. In turn, this would get the students to practice their fractions more frequently, which is needed for them to fully understand and grasp the concepts.

Currently, when the player completes a level exceptionally well, they are rewarded with bonus cash. As of yet, the cash cannot be used to do anything, but students have expressed interest in being able to use the cash to buy things within the game, like different kinds of candy or personalizing the game space by dressing up the characters. Anything to make the game more enjoyable will encourage repeated playing, which, again, will help students comprehend fractions.

Implications

The research team identified numerous instances where the design of the game interfered with game play and potentially disrupted the learning process, running counter to the intentionality of the effort. Game elements that create confusion with the subject matter have the potential to discourage students who wish to avoid feelings of failure. Identifying limitations of the app help underscore the need for greater collaboration between design educators and instructional designers early in the development process. This insight is not new in that Hirumi et al. (2010) have made a similar call for this type of collaboration. On the other hand, the current report provides a case study of the implications of such a call. In line with Hirumi et al.’s proposal, we advocate that EVGs that fail to consider design and usability may miss the opportunity to provide instruction to willing and receptive participants.

The methodology employed by the research team suggests that internal usability testing should be conducted early, and often, during the development process, and certainly prior to deployment. Following the release of the app the research team conducted internal usability testing that identified multiple design weaknesses that had the potential to confuse and frustrate players. These issues were later corroborated by student
feedback in playtesting sessions, suggesting internal sessions are very valuable when identifying usability and design flaws. As the design, development, and deployment of EVGs matures, and interdisciplinary collaboration among many fields invested in design increases, additional reports should emerge. Nevertheless, cases like that for the app demonstrate that much work is needed to coordinate the varying priorities and investments from designers of related fields (Ebner & Holzinger, 2007).

One clear implication of this research demonstrates the capabilities of non-usability experts to identify design issues during internal testing of EVG’s. Prior research indicated usability experts were needed to identify concerns in the usability domain (Dumas, 1999); however, this research demonstrates that experts in usability testing are not necessarily required to identify major usability concerns. As validation for this claim, in the case of this research, playtesting students later validated 100% of the concerns uncovered by the internal research team. For these reasons, EVG designers and developers should being internal usability testing during the initial paper prototyping and design phases in an effort to eliminate usability concerns prior to deployment.

A second implication of this research points to the importance of incorporating qualitative data in the evaluation of EVG’s. The most popular usability methods rely solely on quantitative data streams: time on task, number of errors, number of clicks, etc. (Dumas, 1999) and virtually ignore qualitative data. In the case of evaluating children’s EVG’s qualitative data helps uncover children’s preferences and desires (Hanna, 1999). By applying the BH Method of data analysis, researchers were able to identify emergent themes of particular interest to the students, and moreover, the usability of the app. The research team found the BH Method to be extremely helpful while analyzing the large amount of qualitative data, and encourages the use of this method during the iterative design process.

Early, and often, usability testing could have the potential to save time and resources. More importantly, it could reduce the need for multiple game releases. A student who is confused by one iteration of an EVG may be unwilling to play a later release, even one that addresses the original problems. To produce the best possible game and maximize student participation and engagement, the research team recommends early, and frequent internal gaming sessions to test for usability issues. Though this is a known issue for any game or instructional designer worth their salt, it oftentimes becomes problematic as contingencies such as school calendars compel designers to move forward with “good enough” prototypes. As Winn and Heeter (2006) note, playtesting is the critical point at which these concerns should be identified. Nevertheless, playtesting is not yet subsumed in the instructional designers vocabulary and there are few available prescriptions available to those who design EVGs.

Conclusion

Learning scientists, instructional designers, and content area experts have for some time invested in a notion that video games could be adopted or designed to motivate and engage students in learning (Charsky & Mims, 2008; Dodlinger, 2007; Robertson & Howells, 2008). In this article we have attempted to make a case that design patterns could serve as a lingua franca for designers collaborating from potentially related disciplines: learning sciences, instructional design, and design education. We presented details through a design study on an evolving process of evaluating EVGs for middle school mathematics. Our goals are to not only improve internal workflow processes, but to share with others attempting to leverage the features of recreational video games for intentional learning purposes. Our conclusion is that leveraging gaming design patterns is an effective way to identify areas of strength and weakness when assessing the engagement and learning value of EVGs. The methodology outlined in this report could be adopted to improve or revise processes for designing, developing, and deploying EVGs.

References


Reading, Mass: Addison-Wesley.


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Appendix A: Games for Learning Institute Design Patterns (Kinzer et al., 2010)

1. Constructing things is fun and helps learning
2. Strong Narratives provide sufficient incentive and clear goals to solve hard puzzles/problems
3. Time and resource constraints make games fun and can improve learning
4. First person shooters do not automatically provide incentives to learn
5. Games can be engaging without stunning visuals
6. Games that include summations of statistics or cumulative achievements
7. Kids will engage in rote tasks for small incentives when it leads up to larger incentives later
8. Scaffolding can be used to make games adaptive to learners’ specific needs (prior knowledge, abilities, etc.)
9. Games can be engaging, even addictive, without being always fun
10. The stronger the intrinsic motivation of the game content the less extrinsic motivation is required to engage players
11. A social component (collaboration, competition) makes games fun/engaging
12. Polish: a well-tuned end experience with no rough edges in appearance or interaction is a key factor in making or breaking fun
13. Strong Sense of Progression: game gradually releases information to players and allows contained practice and then mastery that is then built upon, or scaffolded.
14. Character Specialization: The notion that social games such as massively multi-player online games provide structured experiences in which players take on specialized roles and work together to solve problems, providing powerful learning opportunities.
15. Role-playing and emotional engagement with subject matter: game positions the player deeply in the center of a situation, taking on the perspective of others who are faced with the actions and choices and situations that the game portrays.
16. Exploration of moral and ethical dilemmas: game lets players think about and experience dilemmas instead of telling them how to feel or what to do.
17. Exploration of systems – game allows player to viscerally experience abstracted principles, their constraints and possibilities, such as those of physics or engineering.
<table>
<thead>
<tr>
<th>Category</th>
<th>Issue</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Measurement</td>
<td>The ruler lines don't actually line up with anything.</td>
<td>Without a reliable measurement tool it is very hard to visually measure how a fraction relates to the whole.</td>
</tr>
<tr>
<td>Visual Measurement</td>
<td>Candy Bar in tray and on screen should align</td>
<td>It is hard to visually measure how a fraction relates to the whole.</td>
</tr>
<tr>
<td>Visual Measurement</td>
<td>The images in level five transform when being measured, which is very confusing.</td>
<td>It feels visual measurement is not the goal of level five but this is not clearly stated.</td>
</tr>
<tr>
<td>Rewards</td>
<td>Trophies have numbers that do not correspond with their awards - ex &quot;3&quot; might be &quot;10&quot; orders.</td>
<td>It’s difficult to understand what actions will earn a reward.</td>
</tr>
<tr>
<td>Interface</td>
<td>The flat menu is less engaging. I wish the buttons had more action.</td>
<td>Interaction elements are more fun and engaging.</td>
</tr>
<tr>
<td>Interface</td>
<td>The flat screen doesn't immediately look like a touch map.</td>
<td>Lack of visual cues diminish gameplay experience.</td>
</tr>
<tr>
<td>Interface</td>
<td>The green next arrow is hard to find against the brown background</td>
<td>Players lose time trying to locate navigation icons.</td>
</tr>
<tr>
<td>Interface</td>
<td>Next arrow is too small</td>
<td>Players lose time trying to locate navigation icons.</td>
</tr>
<tr>
<td>Game Play</td>
<td>Final ship button has no way to cancel</td>
<td>There’s no way to undo an incorrect answer.</td>
</tr>
<tr>
<td>Game Play</td>
<td>Animations take too long</td>
<td>Slow animations make it difficult to achieve objectives. Time constraints should relate to problem solving.</td>
</tr>
<tr>
<td>Game Play</td>
<td>After selecting the candy you shouldn't have to hit a next arrow. It should just continue after choosing the candy</td>
<td>Redundant actions slow game play.</td>
</tr>
<tr>
<td>Game Play</td>
<td>Shipping the candy has redundant steps. Once I tap ship, it should just ship. Or I should just drag the order to the shipping box. Just one step instead of two</td>
<td>Redundant actions slow game play.</td>
</tr>
<tr>
<td>Game Play</td>
<td>Finger swipes to slice slow down game play, increase errors and add very little to game play</td>
<td>Repeated mechanics that do not add to the learning component and slow game play should be eliminated.</td>
</tr>
<tr>
<td>In-Game Feedback</td>
<td>Boss Cog tells players to go &quot;faster, faster!&quot; regardless of their actual playing speed.</td>
<td>In-game feedback feels inconsistent and distracting.</td>
</tr>
<tr>
<td>In-Game Feedback</td>
<td>Boss Cog blocks the order on higher levels making the participant lose time.</td>
<td>In-game feedback can create visual clutter.</td>
</tr>
<tr>
<td>In-Game Feedback</td>
<td>Boss Cog pops up with multiple warnings that are distracting to game play.</td>
<td>Constant popups break concentration and interrupt game play.</td>
</tr>
<tr>
<td>Narrative</td>
<td>The objective of level five is unclear.</td>
<td>The narrative that introduces level five does not sufficiently explain the goal of this level.</td>
</tr>
</tbody>
</table>
Appendix C: Student Questionnaire

How easy is it to play this game? (1-4)
Would you tell a friend about this game? Yes/No?
If you didn’t have to for class, would you play this game again? Yes/No & Why?
What do you think is really cool about this game?
What don’t you like about this game?
Do you understand fractions better after playing this game?
Ask student about each button on the main menu and what it does.
How many levels have you been able to complete?
What do you think of the characters?
Do you enjoy playing the game? What do you like about it?
What do you think about the game screen? Layout? Swipe actions?
Did the teacher offer enough information on how to play the game?
Is the game easy to understand?
Have you used the tutorial? Was the tutorial helpful?
What do you think about the feedback on the shift log? Is it helpful? How could we improve it?
What do you think about the higher levels? The candy changing?
Was the change in task for the higher levels made clear? How could it be made clearer?
What do you think about the game mechanics? Shipping? Drag to trash?
What do you think about the bonus? Did they make you want to work harder?
Appendix D: Teacher Questionnaire

How would you rate this game overall?
How easy is it for you to play this game?
How easy is it for your students to play this game?
How likely would you be to recommend this game to a friend/colleague?
How effective do you think this game is at teaching your students fractions?
What is your favorite part about this game?
What is your least favorite part about this game?
How many levels have you been able to complete?
How many levels have your students been able to complete?
Do your students enjoy playing the game? What do they like about it?
What do you think about the game screen? Layout? Swipe Actions?
Is this game easy to explain to your students?
Did you find the tutorial helpful?
Did your students find the tutorial helpful?
What could have made the tutorial more helpful and/or effective?
What do you think about the shift log? Is it helpful?
How could it be improved?
What do you think about the higher levels?
How could the change in task be made clearer?
What do you think about the game mechanics? Shipping? Drag to trash?
What do you think about the trophies and the bonus money?
What do your students think about the trophies and the bonus money?
Do they make your students want to work harder?
Do you think this game is engaging? Why or why not? How could this be improved?
Do you think this game is fun? Why or why not? How could this be improved?
Do you think this game is challenging? Why or why not? How could this be improved?
Do you think this game is interactive? Why or why not? How could this be improved?
Do you think this game is rewarding? Why or why not? How could this be improved?
Is there anything else that you would like to see added to this game or any future games?
Appendix E: Student Questionnaire Results

Frequently Cited Issues

- Boss Cog blocks the game space and is distracting
- Game play is slowed by the effort needed to multi-tap or make constant swiping gestures
- Only half of the students understood they could swipe up in order to undo a cut
- Upper levels are nearly impossible to complete in the given amount of time

Overall Game Affinity

<table>
<thead>
<tr>
<th>Question</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate this game overall on a scale of 1 to 4 with one being bad and four being good?</td>
<td>3/4</td>
</tr>
<tr>
<td>How likely would you be to play this game outside of school?</td>
<td>2.6/4</td>
</tr>
<tr>
<td>How likely are you to recommend this game to a friend?</td>
<td>2.9/4</td>
</tr>
<tr>
<td>How much do you think this game has helped you learn fractions?</td>
<td>3/4</td>
</tr>
</tbody>
</table>

Familiarity With Game Menu

<table>
<thead>
<tr>
<th>Task</th>
<th>Percentage of students familiar with task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start a new game</td>
<td>100%</td>
</tr>
<tr>
<td>Load options</td>
<td>100%</td>
</tr>
<tr>
<td>Unlock game levels</td>
<td>68.75%</td>
</tr>
<tr>
<td>Turn sound on/off</td>
<td>87.50%</td>
</tr>
<tr>
<td>Turn timer on/off</td>
<td>93.75%</td>
</tr>
</tbody>
</table>
### Category: GAME PLAY

<table>
<thead>
<tr>
<th>Observation</th>
<th>Interpretation</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No way to track personal progress.</td>
<td>Students want to challenge themselves and track their personal progress.</td>
<td>Provide a login system, which would allow students to track individual progress.</td>
</tr>
<tr>
<td>Students observed using trial and error to solve the problems.</td>
<td>Students discovered ways to ‘drag and compare’ slices before committing to an answer.</td>
<td>Disallow the dragging of images on-screen by locking their location.</td>
</tr>
<tr>
<td>Animations between steps are too slow and make it difficult to ‘race the clock.’</td>
<td>Students are encouraged to play faster; however, they become frustrated with the game mechanics</td>
<td>Streamline gameplay by eliminating or accelerating animations</td>
</tr>
</tbody>
</table>

### Category: CHARACTERS

<table>
<thead>
<tr>
<th>Observation</th>
<th>Interpretation</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boss Cog blocks the order on higher levels.</td>
<td>Gameplay should not be made difficult by bad design decisions.</td>
<td>Reanalyze the game action triangle (area of interaction) and rearrange elements to better facilitate play and engagement, including characters.</td>
</tr>
<tr>
<td>President Carmello does not have a strong presence throughout the game.</td>
<td>Why introduce a character that doesn’t hold a major role in the game narrative?</td>
<td>Consider Carmello as a problem-solving assistant possibly providing prompts when player seems ‘stuck’ on a problem.</td>
</tr>
<tr>
<td>Boss Cog appears often, potentially leading to too much negative prompting.</td>
<td>Negative feedback can lead to disenchantment.</td>
<td>Consider changing back-end intelligence to lessen appearance of Boss Cog.</td>
</tr>
</tbody>
</table>

### Category: GAME MECHANICS

<table>
<thead>
<tr>
<th>Observation</th>
<th>Interpretation</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drag to ship is redundant and slows down game play.</td>
<td>When pressured to compete against the clock, unnecessary interaction frustrates player.</td>
<td>Analyze game-play interactions to eliminate unnecessary interaction.</td>
</tr>
<tr>
<td>Final ship provides no opportunity to cancel.</td>
<td>Warn me before I commit.</td>
<td>Incorporate a ‘back,’ or ‘cancel’ option.</td>
</tr>
<tr>
<td>Excessive number of taps, clicks, swipes, etc. to complete order.</td>
<td>See above.</td>
<td>See above.</td>
</tr>
</tbody>
</table>
Computer-Supported Collaborative Concept Mapping for Learning to Teach Mathematics

Young Hoan Cho, Seoul National University, Seoul, Korea
Nan Ding, University of Missouri
Andrew Tawfik, Concordia University
Óscar Chávez, University of Texas San Antonio

Abstract. Although concept maps have been effectively used for knowledge representation and constructive learning, few studies have investigated how people collaboratively build knowledge with concept maps. The current study explored how pre-service teachers share and integrate their mathematical knowledge for teaching through computer-supported collaborative concept mapping (CSCM) activities. The pre-service teachers compared and integrated their digital concept maps, which represented lesson plans of defining exponential functions through discussions in a classroom. From multiple data sources, this study quantitatively and qualitatively analyzed knowledge building processes as well as benefits and limitations of CSCM. The CSCM contributed not only to the lesson-planning performance but also to collaborative knowledge building. Small groups were actively engaged in quick consensus building and integration-oriented consensus building rather than conflict-oriented consensus building. The limitations of CSCM were discussed for the improvement of the activity in pre-service teacher education.

Keywords: Concept map, computer-supported collaborative learning, lesson plan, mathematics, teacher education

Introduction

Lesson-planning activities are essential for school-based curriculum development (Juang, Liu, & Chan, 2008), lesson study (Fernandez, 2002; Sims & Walsh, 2009), and effective teaching practices. However, a number of pre-service teachers lack the competency of lesson planning and feel uncomfortable in developing new tasks and modifying existing curriculum materials (Ball & Feiman-Nemser, 1988; Grossman & Thompson, 2008; Nicol & Crespo, 2006). As such, it is important to investigate the instructional design that might aide these individuals. For the pre-service teachers with a lack of teaching experience, collaborative lesson planning is beneficial in developing their pedagogical content knowledge and teaching competencies (e.g., Chen, 2012; Sims & Walsh, 2009). Pre-service teachers can negotiate the meaning of pedagogical components like learning objectives, tasks, instructional strategies, and learning materials while collaboratively constructing a lesson plan.

The effectiveness of collaborative lesson planning can be enhanced by using instructional design, such as strategic designs of concept maps. Concept maps have
Concept maps have been used as a cognitive tool to support knowledge representation, conceptual change, in-depth understanding, and problem solving (Jonassen, 2000; Nesbit & Adesope, 2006; Novak, 1990). In the literature of collaborative learning (van Boxtel, van der Linden, & Kanselaar, 2000; Chiu, Huang, & Chang, 2000; Roth, 1994), concept maps encourage learners to identify and elaborate on different viewpoints while carrying out a collaborative task. Engelmann and Hesse (2011) found that learners more actively discussed and shared their different perspectives when they received digital concept maps that represented knowledge structures of collaborators.

Despite the potential benefits of concept maps for instructional design, few studies have explored how concept maps could be used for effective collaborative lesson planning in pre-service teacher education. In the current study, a computer-supported collaborative concept mapping (CSCM) activity was designed to enhance a lesson-planning performance in mathematics teacher education. Moreover, this study explores how pre-service teachers collaboratively build mathematical knowledge for teaching through the CSCM activity and how they perceive the benefits and limitations of the activity. The findings of this study contribute to improving the design of CSCM activities in pre-service teacher education as well as an in-depth understanding of knowledge building processes in CSCM.

Collaborative Concept Mapping

Concept maps as instructional designs visually represent the structure of knowledge including conceptual nodes, links, and linking words that show a relationship between various concepts. Many educators have used concept maps for constructive learning activities in which students visually represent their knowledge with a concept map (Jonassen, 2000; Nesbit & Adesope, 2006). From the student-constructed concept maps, teachers can identify what students know, what they do not know, what they misunderstand, and can therefore enhance formative assessment and adaptive instruction. Moreover, teachers can provide students with well-constructed concept maps as learning materials that foster a conceptual understanding of a novel topic or problem. According to a meta-analysis of previous studies (Nesbit & Adesope, 2006), activities of constructing and studying concept maps were more beneficial for learning outcomes when compared to traditional school activities such as attending lectures and reading texts.

A growing number of studies have investigated collaborative concept mapping as a way to help learners negotiate the meanings of nodes and links (van Boxtel et al., 2000; Chiu et al., 2000; Roth, 1994). By comparing concept maps, learners can explicitly identify differences in nodes, links, and linking words and discuss them to integrate or challenge different viewpoints. Concept maps provide a joint space in which learners can share their knowledge with using such words as “this” and “that” or pointing to the nodes and links in a concept map (Roth & Roychoudhury, 1993). In addition, learners can visually represent what they have discussed about concepts and a relationship between concepts by modifying a concept map. Van Boxtel and her colleagues (2002) argued that the collaborative concept-mapping task is much helpful for articulating thoughts, elaborating the meaning of concepts, and co-constructing conceptual knowledge.

The development of computer-based visualization tools enables learners to create, modify, and share their concept maps efficiently. Computers help to create and revise complex concept maps including a number of nodes and links (Liu, 2011; Royer & Royer, 2004), and the advanced network technology enables learners to construct a concept map with collaborators at a distance. In addition, concept-mapping software can help learners to integrate their concept maps by visually representing what nodes and links are shared or unshared between concept maps (Kao, Lin, & Sun, 2008). It is also possible that learners clearly explain their own concept maps or provide comments to peer concept maps by adding an annotation (i.e., electronic “Post-It” notes) in a digital concept map (Novak & Cañas, 2008). Thus, CSCM can help learners to easily create a concept map, clearly communicate their ideas, and effectively integrate different viewpoints.

However, research has shown the effectiveness of CSCM will be limited when learners are not actively engaged in collaborative knowledge building process (Komis, Avouris, & Fidas, 2002; Liu, 2011) or spend substantial time on such activities as sharing tools and deciding roles, which are not directly related to meaningful learning (Chiu, 2004; Kirschner, Paas, & Kirschner, 2009). The design of the CSCM activity may influence peer interaction patterns, which in turn determine the quality of concept maps and collaborative learning outcomes (Chiu, 2004; Stoyanova & Koppers, 2002). For instance, Van Boxtel and her colleagues (2000) found that elaborative episodes (i.e., elaborated answers, collaborative elaboration of conflicts, and co-constructed reasoning) in the CSCM process were highly correlated to individual learning outcomes. For effective CSCM, instructors should carefully design learning activities to promote collaborative knowledge building and minimize unnecessary or redundant activities that increase extraneous cognitive load (Kirschner et al., 2009).

Design of Computer-Supported Collaborative Concept Mapping

The literature of concept mapping has shown that
three design elements are crucial for effective CSCM: collaboration modes, concept-mapping tasks, and learning environments. First, an instructor should decide how learners interact with each other for CSCM. Stoyanova and Komers (2002) distinguished distributed interaction from shared interaction in CSCM. In distributed concept mapping, learners individually create and revise concept maps based on interaction with group members (Kao et al., 2008), whereas in shared concept mapping learners jointly create a single group concept map through synchronous and direct interaction (Chiu, 2004; Komis et al., 2002; Roth & Roychoudhury, 1993). Stoyanova and Komers found that the shared concept mapping was superior to the distributed concept mapping in individual knowledge acquisition and transfer of knowledge from a group to individuals. For more active participation of all group members, previous studies also encouraged learners to prepare a concept map individually before the shared concept mapping (Molinari et al., 2009; van Boxtel et al., 2000). Van Boxtel and her colleagues (2000) found that learners were more engaged in questioning activities when they individually prepared a concept map before collaboration.

Second, concept-mapping tasks play an important role in CSCM. An instructor can allow students to decide all nodes and links in a concept map by themselves or provide a list of concepts and linking words to reduce their cognitive demands. Lim, Lee, and Grabowski (2009) found that fully generating a concept map was slightly more beneficial for knowledge acquisition than partially generating it (i.e., fill-in-the-blanks). The benefits of CSCM may be larger for a complex task of fully generating a concept map when compared to a simple task of filling in the blanks of a given concept map, which can be completed without the help of learning partners (Kirschner et al., 2011). In addition, learners may be more engaged in CSCM activities when the task is closely related to authentic problems and contexts (Chang, Sung, & Lee, 2003; Engelmann & Hesse, 2010; Liu, 2011). For instance, in a study by Chang et al. (2003), learners created, revised, and shared their concept maps for representing their knowledge and sharing hypotheses of authentic inquiry problems. It is therefore helpful for learners to carry out CSCM with a specific goal like solving a problem closely related to their interests.

Lastly, instructors need to design learning environments where students collaborate to construct concept maps. For CSCM, learners can interact with learning partners in face-to-face, online, or blended learning environments. The Internet and network technologies enable learners to collaborate asynchronously (Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008) as well as synchronously (Engelmann & Hesse, 2010; Komis et al., 2002). Online learning environments help to engage in reflection, critical thinking, and task-oriented discussion because verbal messages can be stored and retrieved whenever they are needed (Jonassen & Kwon, 2001). However, in online learning environments, learners encounter several difficulties in sharing their thoughts and challenging different viewpoints due to the lack of nonverbal cues (Ruberg, Moore, & Taylor, 1996) and delayed responses of unmotivated group members in asynchronous online learning (De Simone et al., 2001). In a synchronous CSCM activity, Chiu and Hsiao (2010) found that approximately 70% of student groups passively participated in the activity or primarily paid attention to social topics unrelated to the CSCM task. By contrast, in a face-to-face environment, learners can negotiate meanings of concepts and their relationships by using nonverbal cues like physically touching concept nodes and drawing a concept map to show what a person intends to say (Roth & Roychoudhury, 1993). It is important to design CSCM learning environments in a way to optimize the affordances of online and face-to-face learning environments and to meet the needs of learners.

From the previous studies above, the current study created three design principles of the CSCM activity. First, learners should develop individual concept maps before integrating them into a group concept map through shared interaction. Second, an authentic problem or task should be integrated with the CSCM activity. Lastly, online and face-to-face learning environments should be used flexibly according to the needs of learners and the purpose of the CSCM task.

The purpose of this study is to gain an in-depth understanding of the CSCM activity in mathematics pre-service teacher education by applying a case study method. By analyzing multiple data sources, this study investigates how learners (i.e., pre-service teachers) interact with each other in CSCM and how they perceive the benefits and limitations of the activity. Because CSCM was seldom applied for learning to teach mathematics in pre-service teacher education, this study intends to identify themes in regards to benefits and limitations of CSCM, as well as knowledge building processes in the activity, which can be beneficial for improving the design of CSCM.

**Methods**

**Participants.** Thirteen pre-service teachers (1 male and 12 females) participated as part of their coursework in the secondary mathematics method course at a Midwestern university in the United States of America (USA). All participants were third-year Caucasian American undergraduates and lacked prior
experience with any concept mapping software. Before the CSCM activity, participants took a training session for an understanding of concept maps and the use of the concept mapping software (CmapTools). Participants were randomly assigned into six groups (5 dyads and 1 triad) for the CSCM activity. The course instructor, an assistant professor with 13 years of secondary mathematics teaching experience, participated in developing tasks and resources for the current study as well as implementing the CSCM activity.

**Tasks and Learning Materials.** Participants received a lesson-planning task that was designed to provide an authentic context and a goal of CSCM. The lesson-planning task required participants to develop a lesson plan for teaching twenty-one 10th grade students a way to identify and define an exponential function from a table. It was assumed that students were taught graphs of exponential functions in the previous lesson. The task also required writing a lesson plan with justifications in terms of learning objectives, learning materials, instructional processes, and assessment. Participants were allowed to use resources in a textbook and the Internet while developing a lesson plan.

In this study, participants individually constructed concept maps to represent their lesson plans with CmapTools and then collaboratively integrated them into a group concept map in a computer room. As shown in Figure 1, concept maps represented a lesson plan with nodes of classroom activities, tasks, learning contents, tools, and learning materials. Links in a concept map described a relationship between two nodes and a procedure of classroom activities. In addition, annotations were used to explain and elaborate a concept map with rationales, examples, student difficulties, and details of learning and teaching activities. The instructor provided participants with a handout which included an instruction of the concept mapping activity, examples of concept maps, and a concept map rubric before they individually constructed concept maps. In addition, the instructor helped participants to understand student difficulties in solving an exponential function problem by analyzing student work examples with participants in a classroom.

Participants integrated their concept maps into a group concept map. The CSCM activity consisted of three steps: (a) explaining individual concept maps to a learning partner(s), (b) comparing individual concept maps and then selecting a concept map to be developed as a group concept map, and (c) collaboratively revising the selected concept map through negotiating the meanings of concepts, links, and annotations. To support this activity, the instructor provided a worksheet including prompts that helped to identify similar and dissimilar

![Figure 1. Digital concept map of a lesson plan](image-url)
features between individual concept maps and to justify why a particular concept map was selected for CSCM.

**Procedure.** Before the CSCM activity, participants were asked to individually create a lesson plan about mathematical reasoning with conditional statements. The pre-lesson planning task was given to examine participants’ initial lesson-planning performance. A different topic was selected from the lesson-planning task carried out after the CSCM activity to prevent the practice effect, although the two tasks had the same requirements. In addition, participants learned the principles of concept maps and practiced using CmapTools for two regular class periods.

The CSCM activity was carried out in three phases for two weeks. First, participants received the lesson-planning task and searched for the information and resources that were necessary for teaching the exponential function. Second, participants individually constructed a concept map to represent a lesson plan with CmapTools and shared it using CmapServers, which allowed participants to create, modify, and share their concept maps online (Novak & Cañas, 2008). Lastly, participants integrated individual concept maps into a group concept map through discussions in a computer room for 75 minutes. Participants shared a computer with their learning partner(s).

After the CSCM activity, participants individually created a lesson plan based on their group concept map and took a survey about their perception of CSCM. In addition, six participants recruited from different groups were interviewed in regard to their perceptions of benefits and limitations of the CSCM activity. Each person was interviewed individually for approximately one hour.

**Data Collection and Analysis.** Multiple data sources were employed to investigate research questions. In the phase of integrating individual concept maps into a group concept map, discourses between learning partners were all recorded and transcribed for the analysis of peer interaction patterns. Transcripts of audio records were segmented into idea units, and two researchers independently coded the idea units according to the seven categories in Table 1. The coding scheme was developed based on the studies by Weinberger and Fischer (2006) and Hmelo-Silver and Barrows (2008). Inter-rater reliability (Cohen’s kappa) ranged from .91 to .94, and disagreements were all resolved through discussions.

Lesson plans were collected before and after the CSCM activity. Two researchers later independently assessed the quality of lesson plans with the lesson plan rubrics that were developed based on Boston and Smith (2009) and Panasuk and Todd (2005). For each category of tasks (an understanding of mathematical concepts and meanings behind procedures), instruction (effectiveness of instructional strategies for achieving learning objectives), students (instruction based on students’ prior knowledge and difficulties), and justification (well-elaborated reasons to support instructional decisions), lesson plans were rated from 0 to 3 points. Inter-rater reliability (Cohen’s kappa) ranged from .74 to .94, and all disagreements about the qualities of lesson plans were resolved through discussions.

The survey conducted after the CSCM activity included five items about satisfaction (e.g., “I am satisfied with the concept mapping activities,” “I am disappointed with the way the concept mapping activities worked out”) and seven items about participation in CSCM (e.g., “We challenged each other’s ideas,” “All group members participated in creating a group concept map”) in a 5-point Likert scale ranging from “strongly disagree” to “strongly agree.” The reliability of survey items (Cronbach’s alpha) was .84 for the satisfaction items and .79 for the participation items.

Semi-structured interviews were carried out in order to identify benefits and limitations of CSCM. Interview

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Externalization</td>
<td>Articulating thoughts to a learning partner</td>
</tr>
<tr>
<td>Elicitation</td>
<td>Asking a question or provoking a reaction from a learning partner</td>
</tr>
<tr>
<td>Agreement</td>
<td>Accepting the contribution of a learning partner to move on with the task</td>
</tr>
<tr>
<td>Integration</td>
<td>Taking over, integrating, and applying the perspective of a learning partner</td>
</tr>
<tr>
<td>Challenging</td>
<td>Disagreeing, modifying, or replacing the perspective of a learning partner</td>
</tr>
<tr>
<td>Meta</td>
<td>Planning, monitoring, and coordinating the CSCM task</td>
</tr>
<tr>
<td>Off-task</td>
<td>Talking about a topic unrelated to the CSCM task</td>
</tr>
</tbody>
</table>

Table 1. Peer Interaction Categories
transcripts were analyzed based on the grounded theory approach (Glaser & Strauss, 1967). Three researchers individually identified categories from interview transcripts and then compared their categories to synthesize different viewpoints on the interview data. They repeatedly labeled and discussed the relationships between categories until saturation was achieved. After articulating the properties of categories and their relationships, the researchers coded the interview transcripts again with final categories and subcategories that emerged from raw data.

Findings

Collaborative Knowledge Building in CSCM

Participants integrated two or three concept maps into a group concept map through discussions. According to the survey (5-point scale), participants perceived that they were actively engaged in the CSCM activity ($M = 4.2$, $SD = .35$). As shown in Table 2, discussion messages included an average of 161.8 idea units. Group F, with three participants (total 251 idea units), discussed more actively than other groups with two participants. When participants externalized their thoughts about the concept maps (28%), their learning partner was likely to ask a question (14%), accept the opinion (16%) or integrate it with his or her own opinion (9%). In addition, participants often planned, monitored, and coordinated CSCM processes (17%). However, the low percentage of challenging messages (4%) indicated that participants were not actively engaged in conflict-oriented consensus building.

A sequential analysis was conducted to examine whether a particular message was likely to follow a given message (Bakeman & Gottman, 1997). Transitional probabilities of target messages following a particular given message were calculated and then z-scores of transitional probabilities were tested at the significance level of .05. Figure 2 shows the transitional probabilities between discussion messages in which challenging, meta, and off-task messages were excluded because they were not significantly related to other message types. After a participant stated a new idea about a concept map, his or her learning partner was likely to ask a question (transitional probability = .23), agree on the idea (.23) or integrate it with other ideas and instances (.17). Elicitation was likely to be followed by externalization (.42). In addition, integration tended to be followed by elicitation (.22), agreement (.24), and the other integration (.21). These peer interaction patterns show that small groups were engaged in quick consensus building and integration-oriented consensus building (Weinberger & Fischer, 2006) rather than conflict-oriented consensus building.

Peer interaction patterns were compared across six groups. According to Teasley (1997), transactive interaction in which learners elaborate or challenge the reasoning of a learning partner positively influences individual learning outcomes. In this study, some groups (Groups B, C, E, and F) showed more transactive interaction patterns than other groups (Groups A and D), whose aggregate percentages of integration and challenging messages were below the mean percentage (13%). In Group A, for instance, participants quickly built a consensus about their group concept map (22%) without further integration (2%) or challenging (3%) messages and frequently chatted about topics irrelevant to the concept-mapping task (25%). In the following excerpt (Figure 3), for instance, two participants shared their thoughts about a lesson plan along with simple agreements. As a result, they quickly made decisions about their group concept map, but they did not deeply negotiate the meanings of concepts, links, or annotations.

By contrast, Group C showed more transactive peer interaction patterns. The percentages of integration (10%) and challenging (7%) messages were above the mean percentages. In the following discourse (Figure

<table>
<thead>
<tr>
<th>Group</th>
<th>Externalization</th>
<th>Elicitation</th>
<th>Agreement</th>
<th>Integration</th>
<th>Challenging</th>
<th>Meta</th>
<th>Off-task</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n=2)</td>
<td>35(22%)</td>
<td>12(8%)</td>
<td>34(22%)</td>
<td>3(2%)</td>
<td>4(3%)</td>
<td>29(19%)</td>
<td>39(25%)</td>
<td>156</td>
</tr>
<tr>
<td>B (n=2)</td>
<td>49(30%)</td>
<td>31(19%)</td>
<td>28(17%)</td>
<td>22(13%)</td>
<td>4(2%)</td>
<td>20(12%)</td>
<td>9(6%)</td>
<td>163</td>
</tr>
<tr>
<td>C (n=2)</td>
<td>31(27%)</td>
<td>10(9%)</td>
<td>14(12%)</td>
<td>11(10%)</td>
<td>8(7%)</td>
<td>20(17%)</td>
<td>21(18%)</td>
<td>115</td>
</tr>
<tr>
<td>D (n=2)</td>
<td>39(35%)</td>
<td>21(19%)</td>
<td>19(17%)</td>
<td>6(5%)</td>
<td>4(4%)</td>
<td>17(15%)</td>
<td>7(6%)</td>
<td>113</td>
</tr>
<tr>
<td>E (n=2)</td>
<td>52(30%)</td>
<td>21(12%)</td>
<td>22(13%)</td>
<td>18(10%)</td>
<td>8(5%)</td>
<td>30(17%)</td>
<td>22(13%)</td>
<td>173</td>
</tr>
<tr>
<td>F (n=3)</td>
<td>63(25%)</td>
<td>44(18%)</td>
<td>35(14%)</td>
<td>30(12%)</td>
<td>10(4%)</td>
<td>47(19%)</td>
<td>22(9%)</td>
<td>251</td>
</tr>
<tr>
<td>Mean</td>
<td>44.8(28%)</td>
<td>23.2(14%)</td>
<td>25.3(16%)</td>
<td>15(9%)</td>
<td>6.3(4%)</td>
<td>27.2(17%)</td>
<td>20(12%)</td>
<td>161.8</td>
</tr>
</tbody>
</table>
4), for example, pre-service teachers challenged and integrated their opinions about student activities in a lesson plan. C1 initially planned to provide student groups with mathematics problems and later asked a question to C2 to garner her opinion about an alternative plan to collect data from students. The two participants reciprocally agreed, challenged, and integrated their thoughts. Their collaboration created a new plan of allowing students to make their own table with a common ratio.

Group C was more actively engaged in transactive peer interaction than Group A. Consistently, an interview with C1 revealed that he negotiated different viewpoints with his learning partner without any defensive attitude: “We could honestly agree which one was the better idea instead of being really defensive.”

**Benefits and limitations of CSCM**

The lesson-planning performance was assessed with rubrics in terms of tasks, instruction, students, and justification. As shown in Figure 5, there was no significant difference in the task quality between pre- and post-lesson plans, $t(12) = 1.59, p = .137$. However, CSCM was beneficial for the lesson planning performance in regards to instruction, $t(12) = 2.21, p = .047$, students, $t$

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**Figure 2. Sequence of peer interactions ($^* p < .05$, $^{**} p < .001$)**

1. A2: I started with a review of graphs, questions too. I did like when they walked into the room, they would get a card. It would either have a graph or formula on it, and they would have to find the person that was their match.

2. A1: Oh, that’s cool.

3. A2: I got that idea actually from the pre-service math teacher conference this past weekend. So, we did it with like cartoons, but it was kind of cool. That was how we found our group. We both started with a review of graphs of exponential functions.

4. A1: Okay. I know the next part that I did after the warm up. I guess I assumed that they didn’t do much with tables before, so I had them make tables from the given exponential function. Then, they started to look at patterns there.

5. A2: That’s a good idea.

**Figure 3. Quick consensus building in Group A**
since we are working in groups of 2 to 3 on a problem list I have prepared, give them additional practice making equations from tables. So instead of a list that I’ve prepared, do you think we could collect some data?

2. C2: Yeah. I mean it would have to be.

3. C1: To make it a little more worthwhile instead of just doing problems?

4. C2: Yeah, but if you were collecting data it would have to be something that you need to control to start exponential functions.

5. C1: That’s true.

6. C2: Like after I got to working on mine, I was thinking because you couldn’t just plug in random data.

7. C1: Ok so have them make their own table that would show...

8. C2: The table would have to have a common ratio. That would be the stipulation.

Figure 4. Transactive peer interaction in Group C

(12) = 4.38, \( p = .001 \), and justification, \( t (12) = 2.94, p = .012 \). In the post-lesson plan, pre-service teachers applied more effective instructional strategies for achieving learning objectives (\( M = 2.62 \) vs. \( 2.08 \)) and considered students’ prior knowledge and difficulties (\( M = 2.38 \) vs. \( 1.46 \)) more than in the pre-lesson plan. In addition, participants more effectively justified their instructional decisions in the post-lesson plan, compared to the pre-lesson plan (\( M = 2.54 \) vs. \( 2 \)). As such, these results show that CSCM instructional strategies helped pre-service teachers to construct higher quality lesson plans.

Although lesson-planning performance improved through CSCM, participants conveyed both positive and negative perceptions toward the CSCM activity. The survey showed that participants neither agree nor disagree on the statements of satisfaction (\( M = 2.8, SD = .84 \)). From interviews with six participants, their perceptions of CSCM were identified and categorized in regard to benefits, limitations, and suggestions for the activity. As shown in Table 3, benefits of CSCM included four major categories: mathematical knowledge for teaching, helpfulness of concept mapping, usefulness of CmapTools, and collaborative knowledge building. Limitations of CSCM also included four major categories: redundant tasks, low motivation of learners, ineffective collaboration, and obstacles in concept mapping. Lastly, there was a suggestion about instructional

Figure 5. Means and standard error bars of lesson plan scores
supports for CSCM. The major categories included 2-5 minor categories, which were classified into “frequent,” “sometime,” and “rare” categories according to the number of interviewees who stated the same idea for each category.

Interviewees perceived that the CSCM activity was helpful for developing their knowledge of the exponential function, effective instructional strategies, and student difficulties in solving exponential function problems. In addition, they described helpfulness of digital concept maps as an instructional design for mathematics learning and teaching, representing ideas visually, and preparing a lesson plan. For instance, D1 perceived that concept maps helped her to organize lesson plans: “I think a concept map was a really good way to organize your thought process. Like, this is what I am going to do in the beginning, and this is what I am going to do in the middle.” In addition, A2 perceived that concept maps were helpful for identifying students’ difficulties: “Concept maps helped me see how students are going to think about it, and whether they are going to be confused.” Interviewees also perceived the usefulness of CmapTools as an instructional design tool for constructing concept maps.

Interviewees frequently stated the benefits of CSCM for collaborative knowledge building. Participants perceived that it was helpful to share multiple perspectives on a lesson plan and to compare their individual concept maps. For instance, A1 described that her concept map included more student-centered activities and discussions, whereas her learning partner’s concept map included more teacher-directed activities and problem solving practices. In addition, participants learned new

<table>
<thead>
<tr>
<th>Major and minor categories</th>
<th>Frequent</th>
<th>Sometimes</th>
<th>Rare</th>
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<tbody>
<tr>
<td>Benefits of CSCM</td>
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<tr>
<td>1. Mathematical knowledge</td>
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<td>of an exponential function</td>
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<td>Instructional strategies</td>
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<td>in mathematics class</td>
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<td>Student difficulties</td>
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<td>in solving exponential</td>
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<td>function problems</td>
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<td>2. Helpfulness of</td>
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<td>concept mapping</td>
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<td>Helpful for lesson</td>
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<td>3. Usefulness of</td>
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<td>CmapTools</td>
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<td>Easily using CmapTools</td>
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<td>4. Collaborative</td>
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<td>Sharing multiple</td>
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<td>Identifying differences</td>
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<td>between concept maps</td>
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<td>Getting a great idea</td>
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<td>from a learning partner</td>
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<td>Challenging ideas and</td>
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<td>correcting errors</td>
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<tr>
<td>Limitations of CSCM</td>
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<tr>
<td>5. Time-consuming tasks</td>
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<td>Lack of time for the</td>
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<td>Redundant tasks</td>
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<td>6. Low motivation</td>
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<td>Preference toward</td>
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<td>outlines</td>
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<td>Preference toward</td>
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<td>individual concept</td>
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<td>mapping</td>
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<td>7. Difficulty in concept</td>
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<td>mapping</td>
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<td>Lack of understanding</td>
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<td>Difficulty in making</td>
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<td>an exponential function</td>
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<td>8. Ineffective collaboration</td>
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<td>Lack of disagreement</td>
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<td>and negotiation</td>
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<td>Unhelpfulness of</td>
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<td>to resolve disagreements</td>
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<tr>
<td>Suggestion to improve CSCM</td>
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<tr>
<td>9. Instructional support</td>
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<tr>
<td>More options that learners can select</td>
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<td>More guide on concept mapping</td>
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<tr>
<td>More feedback of an instructor</td>
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<td>x</td>
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</table>

Note. Frequent = 5-6 persons; Sometimes = 3-4 persons; Rare = 1-2 persons
instructional strategies from peers through discussions of what learning activities should be included in a group concept map of the lesson plan. For instance, F1 described that she learned a new instructional strategy from her group member when she said:

I thought that half the students would have worksheet A and half would have B, but she actually has every two students have different worksheets. The students actually have to find one another and discuss what they are looking for ... So, I thought that was a good assessment tool, and it is good for getting students to work together.

Perceived limitations of the CSCM activity included time-consuming tasks, low motivation of learners, difficulty in concept mapping, and ineffective collaboration. Four interviewees expressed a desire for more time in comparing and integrating individual concept maps: “There is not really time to develop a whole other lesson plan, like from it [an individual concept map] in the class period (A1).” They also pointed out the redundancy between creating a concept map and writing a lesson plan because annotations in a concept map included details of a lesson plan. In addition, two interviewees preferred making an outline to creating a concept map for the lesson plan: “It makes more sense to just have it written in an outline form and then it would be a lot easier to write up an actual lesson plan (F1).”

The low motivation of learners was related with the usability difficulties in developing a lesson plan with digital concept maps: “With a concept map, if you forget something, you have to alternate and change so many things on your concept map and move them all around because things have to be built up of one another (F1).” Some interviewees also perceived that it was difficult to know when annotations were necessary and how detailed they should be, although they rarely stated difficulties in creating concepts and links with CmapTools. Lastly, the lack of disagreement and negotiation was sometimes perceived as a limitation of the CSCM activity. This perception was consistent with a low percentage of challenging idea units (4%) in Table 2. In addition, three interviewees perceived that comparison of concept maps was not much helpful because their own concept map was similar with that of their learning partner.

Although interviewees rarely requested more instructional supports like feedback and resources, some interviewees wanted more options in creating a concept map and a lesson plan: “If he [instructor] would have given us another option and explained that option well, then I think a lot of us would have been more interested because we could have done it differently (C1).” Three interviewees expressed a desire to have more autonomy in deciding the format of a lesson plan (concept map vs. document) and a tool for collaborative lesson planning (concept map vs. outline).

Discussion

The current study designed the CSCM activity based on instructional design principles synthesized from previous studies. The instructional design principles were applied to the context of mathematics teacher education in which pre-service teachers developed a lesson plan on the exponential function. A case study was carried out for an in-depth understanding of collaborative knowledge building processes in CSCM as well as benefits and limitations of CSCM in mathematics teacher education. In this study, the CSCM activity was unique when it came to the object of CSCM (i.e., a lesson plan) because previous studies mainly focused on visualizing subject matter knowledge with a concept map (Bolte, 1999; Martin, 1994). In order to create a lesson plan with a concept map, pre-service teachers need to use both subject matter knowledge and pedagogical content knowledge.

This study found that participants (i.e., pre-service teachers) actively participated in CSCM for developing a lesson plan. Participants perceived their active participation in collaborative knowledge building through CSCM, and most discourses (88%) were closely related to the CSCM task. When compared to the study by Chiu and Hsiao (2010), the percentage of discourses pertaining to collaborative knowledge building (i.e., externalization, elicitation, agreement, integration, and challenging) was relatively high (71%). However, small groups were more engaged in quick consensus building and integration-oriented consensus building rather than conflict-oriented consensus building. Consistently, in the interviews, some participants perceived the lack of disagreement and negotiation as a limitation of the CSCM activity.

Future studies could employ instructional designs to increase conflict-oriented consensus building, which is beneficial for meaningful learning. Nussbaum (2008) asserted that “difference of viewpoints can trigger sociocognitive conflict, and when this conflict is resolved through discussion and hypothesis testing, better and more lasting learning is obtained” (p. 351). To facilitate conflict-oriented consensus building, an instructor could organize groups of learners who have different viewpoints from each other. In addition, it is recommended to use a CSCM instructional design tool that can automatically highlight different nodes and links between individual concept maps (Kao, Lin, & Sun, 2008).
However, learners who do not have social affinity with their learning partners may not be engaged in conflict-oriented consensus building even if they identify different viewpoints during CSCM. It is also necessary to promote a sense of community and trust among group members (Jones & Isroff, 2005; Rovai & Lucking, 2003) and to prevent learners from interpreting critiques as attacks or win-lose competitions (Rourke & Kanuka, 2007).

The present study explored both benefits and limitations of CSCM. Data analysis revealed the CSCM activity positively contributed to the lesson-planning performance. In addition, interviewees perceived that CSCM was beneficial for the development of mathematical knowledge for teaching and for collaborative knowledge building. These findings were consistent with previous studies that showed the effectiveness of collaborative concept mapping for articulating ideas, elaborating meanings, and sharing different viewpoints (Engelmann & Hesse, 2010; van Boxtel et al, 2000). In this study, the benefits of CSCM might be caused by the design principles of (a) integration of individual concept maps into a group concept map, (b) CSCM for authentic problem solving, and (c) blended learning environments for CSCM.

Beyond the instructional design tool, this study also found limitations of the CSCM activity (see Table 3). For the improvement of the activity, it is necessary to reduce redundant tasks and provide more autonomy in CSCM as well as facilitate conflict-oriented consensus building discussed above. Mayer and Johnson (2008) found that redundancy can be helpful for learning when repeated information fosters essential knowledge construction process without increasing extraneous processing. However, a redundant task may not be beneficial for learning when it increases extraneous processing without contributing to essential processing for knowledge construction. In order to prevent redundancy, it is recommended to write justifications of a concept map without details of a lesson plan that is already visually represented in the concept map.

In the current study, some participants suggested to provide more autonomy in deciding the format of a lesson plan and a tool for collaborative lesson planning. According to the self-determination theory (Ryan & Deci, 2000), autonomy supports are essential for promoting intrinsic motivation in learning. The lack of autonomy might be closely related to the low motivation of learners, which was also identified as a limitation of CSCM. It is necessary to support autonomy of learners by allowing them to select one of multiple options in regard to CSCM design elements. However, an instructor should be cautious when learners lack knowledge of the CSCM task because the increased cognitive load due to the autonomy can hinder novice learners from focusing on negotiation of meanings (Kalyuga, 2007). Thus, an instructor should control the autonomy level according to previous knowledge and experience of learners. In the future research, the design principles suggested in this study should be applied and evaluated in multiple contexts for pre-service teacher education.

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About 15 years ago, I wrote an initial proposal for a journal that would address the practice of instructional design. Then in 2010, I had the opportunity to develop the idea and propose the development of the Journal of Applied Instructional Design. The goal of this journal was to bridge the gap between theory and practice of instructional design by providing practitioners and academics a means for exploring the practice of instructional design. At the time, there was not an applied instructional design journal with high scholarly standards. It was my goal to propose a journal that could provide a means for practitioners and academics to make significant contributions that would lead to improvements in practice, teaching, and study of instructional design. The following essay focuses on the importance of this journal and the contribution it can make to the field of instructional design. I am using the term practitioner for instructional designers who work designing instruction in a variety of settings and academics to refer to faculty in higher education.

I proposed a journal that would be peer reviewed to ensure high quality articles. This journal, however, would not focus on rigorous research design and data collection standards we expect in ETR&D. Rather, I wanted to encourage practitioners and practitioners and academics to collaborate on quality research and conceptual articles based the practice of instructional design. For example, a practitioner working in industry might not have the resources or time to conduct a highly controlled study. However, they often collect data in the form of formative evaluations and observations of implementations leading to valuable insights that could lead to more rigorous controlled studies. In an earlier article, we described these articles as pre-research, that is, articles that suggest an approach of designing instruction or for improving the quality of the instruction that could provide a basis for research study (Morrison & Adcock, 1999). These articles, though, have an intrinsic value of their own. First, they can provide valuable information to other instructional designers in their work. While formative evaluations are designed for a specific case and often have little generalizability, the lessons learned from the evaluations can prove useful to others. Second, practitioner based articles can provide faculty with examples of realistic applications of instructional design in a variety of settings. The experiences from these articles can provide for a richer context and examples than one based on how to solve a math problem or how to setup a video projector (or depending on your age, how to thread a 16mm projector).

The Practice of Instructional Design and Reflection

Instruction design is an academic field reflected in numerous articles published in journals ranging from ETR&D to the Journal of Educational Psychology. Articles range from conceptual and theoretical pieces to intervention studies to qualitative studies to policy studies. However, instructional design is also a field of practice. This field of practice draws from the instructional design knowledge base to make informed instructional decisions. Outside of occasional informal communications and a relatively few studies, our scholarly research is seldom informed by the practice of instructional design. Thus, a journal like the Journal of Applied Instructional Design can provide one means of informing our scholarly research.
Instructional design is based on heuristics that are created and modified through practice (Morrison, Ross, Kalman, & Kemp, 2013; Romiszowski, 1981). Heuristics are general strategies designers use to solve problems in contrast to a rule-based approach that lacks flexibility. A key component of a heuristic approach is the designer’s reflection on the instructional design process. Romiszowski (1981) describes a heuristic process and Schön (1983) describes a reflection process by practitioners as one of observing, experimenting, and testing hypotheses. If instructional designers can document this process, it could lead to substantive articles for this journal that make a significant contribution to our knowledge base. Such articles would also help inform the research and theory in the field of instructional design as well as the teaching of instructional design.

In addition to requiring research classes in our curriculum, faculty should also consider integrating reflection into the core instructional design courses to help students develop the skill. While reflection would be helpful for all students, it could become a particularly useful tool for practitioners to use as a basis for making scholarly contributions to the field. These contributions would build on the qualitative, quantitative, and mixed methods approaches students learned in graduate school. However, we might not expect the same rigor of research design when employed in a practical setting. As a field, we need to recognize the value of field-based research and help develop appropriate methods and standards so that practitioners can make contributions to our knowledge base.

Contributions from Practitioners

My goal in proposing this journal was to provide a means for those practicing instructional design a place to publish scholarly papers. Initially, I conceived three types of papers, but would not limit the focus of the journal to these three. The first category was papers based on reflections of a project and the resulting heuristics. For example, a designer might find a more efficient approach to a subject-matter expert interview when doing a concept analysis. Upon reflection, this approach could be translated into one or more heuristics that could published as paper. Second, a designer might publish an article based on a formative evaluation discussing the instruments and implementation with an analysis of the strengths and weaknesses of the evaluation. Consider a study by Burton and Aversa (1979) that considered the effectiveness of using scripts, scratch tracks, and rough cuts as part of a formative evaluation. Applications of new and unique formative evaluation strategies are often lost when the project is completed. This journal can provide a means of publishing articles describing these techniques. Third, developmental testing, small group testing, and field tests often test instructional interventions (Hsieh et al., 2005), but in a less controlled manner than we might in a research setting. Yet, the results of these formative evaluations can provide additional insights as they typically include learners who are motivated and have a reason to master the content. In contrast, the typical sophomore educational psychology students/subjects may not care how the brakes of a car work and are only interested in the incentive bonus points. Our prior research has found the benefits of a performance incentive compared to the typical task incentive of bonus points focused on learning unrelated content (Morrison, Ross, Gopalakrishnan, & Casey, 1995). Formative evaluations and traditional studies conducted in the field with performance incentives can provide us with valuable feedback and improve our understanding of how different instructional interventions work.

Academics and practitioners should consider submitting manuscript to this journal to better inform the field of the practice of instructional design. As a field, we need to refine the standards for scholarship for publishing data from field-based studies in the field of instructional design.

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The Design and Implementation of an Educational Multimedia Mathematics Software: Using ADDIE to Guide Instructional System Design

Nasrin Moradmand, The University of Western Australia
Amitava Datta, The University of Western Australia
Grace Oakley, The University of Western Australia

Abstract. Disconnection between theory for designing educational applications and theory relating to the application of technology in classrooms, as well as a lack of alignment between technology, curriculum and pedagogy, have been highlighted as main issues that can hamper the quality and relevance of existing computer-based educational applications. The study reported in this paper addressed this disconnection and lack of alignment through the development of a strong educational framework and use of an appropriate instructional system design (ISD). The components of the framework are described in this article, followed by a discussion of the process of applying the defined instructional design principles to the creation of the My Maths Story project’s interactive multimedia mathematics software. The entire implementation and evaluation process of the multimedia instructional materials, which targeted the teaching and learning of mathematics in the lower primary classrooms, is also presented.

Keywords: Instructional system design, mathematics education, multimedia software, cognitive learning

Introduction

In recent years, the teaching and learning of mathematics through computer-based education applications has grown. In the primary classroom, which in Australia covers Years 1 to 6 (children aged 6 to 11), there are many opportunities for computer-based technology to be used to enhance the teaching of curriculum areas such as English and Mathematics (Lim & Oakley, 2013). However, many studies and computer-based applications that are currently used in Australia originate from the USA and, in recent years, from other countries such as the UK and India (Eng, 2005; Moradmand, Datta, & Oakley, 2013; Yelland, Australia. Dept. of Education, & Affairs, 2001). Subsequently, educational software packages are mainly based on the curricula and preferred pedagogies of these countries.

Furthermore, it has been pointed out that there is often a disconnection between theory for designing educational applications and theory relating to the application of technology in classrooms (Offer & Bos, 2009), as well as a lack of alignment between technology, curriculum and pedagogy (Mumtaz, 2000; Robin, 2008; Yelland, Australia. Dept. of Education, & Affairs, 2001). Thus, in many cases, sourcing computer-based technology and applications to facilitate learning in a manner that is pedagogically acceptable to teachers has become an area of challenge for Australian schools.

The purpose of the study reported here was to bridge this disconnection (between theory for designing
Pedagogy in mathematics

Teachers can provide opportunities for students to learn and understand mathematics concepts in various ways. Many instructional strategies exist and several approaches may be utilised throughout any teaching and learning process. In the field of mathematics education for young children, inclusion of children’s literature (storytelling) in the teaching and learning of mathematics is supported by a growing body of research (Goral & Gnadinger, 2006; Haven, 2000; Robin, 2008; Thiessen, 2004; Ward, 2005; Wilburne, Keat, & Napoli, 2011; Zazkis & Liljedahl, 2009). Haven (2000), stated: “Telling a story creates more vivid, powerful and memorable images in a listener’s mind than does any other means of delivery of the same material” (p. xvii).

It has been claimed that mathematics concept storybooks provide a rich and engaging context for promoting children’s mathematical explorations, reasoning and critical thinking throughout early grades (Goral & Gnadinger, 2006; Ward, 2005; Wilburne et al., 2011; Zazkis & Liljedahl, 2009). To provide opportunities for children to make connections between the mathematics concepts in storybooks and the mathematics in their own world, teachers can use a variety of strategies, including explicit teaching, fluency building (skill building) and problem solving.

Explicit teaching involves directing students’ attention toward particular learning objective through a sequence of supports, involving: setting a purpose for learning (telling students what they are going to learn), which should be based on the teacher’s understanding of what students already know; telling students what to do, then showing them how to do it. This is followed by providing guidance on children’s hands-on application of the new learning (Boyles, 2001).

‘Fluency’ is the ability to express something effortlessly, clearly and with automaticity (ACARA, n.d.). Mathematics fluency can be described as the ability to compute maths facts (for example, addition, subtraction, multiplication and division) and problems quickly and with confidence (Mercer & Miller, 1992; Tait-McCutcheon, Drake, & Sherley, 2011). The recall of basic facts is recognised as a vital goal of mathematics education in primary schools since the prompt recall of mathematics facts can ensure that students have the cognitive capacity to attend to the more complex activities of problem solving and higher-order processing (Tait-McCutcheon et al., 2011). Fluency building or skill building is an instructional strategy that “promotes the acquisition of knowledge or skill through repetitive practice” (Adams, 2007, p. 72) in order to learn or become proficient.

‘Problem solving’ can be described as a process of knowing a problem, considering all the details of the problem and working though the details of the problem to reach a solution, and is recognised as a very important task in mathematics education (Lazakidou & Retalis, 2010). Elshout (1987) identifies problem solving as a cognitive function that requires the problem solver to recall and process the relevant information. Although the construct of problem solving has no commonly accepted definition in mathematics education, it undoubtedly involves higher order thinking (HOT), which depends to a large extent on the fluency of lower level learning.

In the teaching of mathematics, research studies have shown that multiple representations (presenting and demonstrating information in more than one medium to support specific kinds of learning) have an important role in developing children’s understandings of mathematics concepts (Carpenter, Fennema, Franke, Levi, & Empson, 1999; Gray, Pitta, & Tall, 1997; Harries & Barmby, 2007; Mishra & Sharma, 2005; Thompson, 1999) and can serve as significant teaching aids for learners, because each representation contains important information for learners. Engaging in multiple representations can enable learners to better understand, develop, and communicate different mathematical attributes of the same object or operation, along with connections between them (Carpenter et al., 1999; Harries & Barmby, 2007; Mishra & Sharma, 2005). There is a variety of ways in which multiple representations can be used to convey mathematics concepts, and computer-based technology has been identified as being capable of providing this (Goldin & Shteingold, 2001; Milovanović, Takači, & Milajić, 2011). The use of multimedia and computer-based tools can facilitate the learner’s abstract educational computer-based applications and theory concerned with applying these educational applications to teaching in mathematics classrooms) through the use of an appropriate instructional system design (ISD). The paper consists of two main sections. It first reviews the mathematics pedagogies and a variety of pedagogical strategies in the mathematics learning area within in early primary levels of school, along with a description of the ADDIE instructional system design components. The study’s educational framework, which incorporates the cognitive learning theory of the Bloom/Anderson taxonomy (2001) to shape and define computer-based instructional materials, is also presented. The second part of this paper discusses the process of applying the defined instructional design principles to the creation of the My Maths Story project’s interactive multimedia mathematics software. The paper presents the implementation and evaluation process of the multimedia instructional materials for assisting in the teaching and learning of mathematics in lower primary school, based on the ADDIE framework components.
thinking and allow multiple representations to be linked dynamically between concrete and symbolic representations. The current study used these two approaches (storytelling and multiple representations) to teaching mathematics as a basis for designing new interactive multimedia software for the teaching and learning of mathematics in the lower primary classroom.

**Instructional system design: the ADDIE framework**

Instructional system design is described as “[T]he systematic development of instructional specifications using learning and instructional theory to ensure the quality of instruction” (Moallem, 2001, p. 113). It includes the entire process of: the analysis of teaching and learning needs and learning objectives; and the development of an instructional system that meets those needs. Most instructional design models have systematic and similar components, but can vary greatly in the specific number of phases (Briggs, 1997; Dick & Carey, 1996; Merrill, 1994). Seels and Glasgow (1998) identified five common components of instructional design and developed the general ADDIE model. ADDIE is an acronym for (1) analyse, (2) design, (3) develop, (4) implement, and (5) evaluate. The ADDIE model is a systematic instructional design model, which represents a dynamic and flexible guideline for building effective teaching and learning tools. Different activities in the various phases of the ADDIE model is summarised in figure 1.

**Theoretical Framework: the composition of educational framework and instructional system design components**

One of the main aims of the study was to design and develop a dynamic computer-based multimedia application to facilitate the teaching and learning of mathematics concepts in primary classrooms. To create such a dynamic system, (a) a systematic system design process, and (b) an educational framework, were required. They were then applied in order to target the specified educational objectives. The ADDIE framework, explained above, was used as a systematic instructional design model which provides a step-by-step procedural blueprint for: the analysis of the teachers’ and learners’ needs; the definition of the goal/s of instruction; the design and development of multimedia materials and tools to assist in the transition; and the evaluation of the effectiveness of the educational intervention.

The study being reported here draws on a cognitivist approach to learning, which focuses on mental

![Figure 1. Summary of activities in the various phases of the ADDIE model of instructional system design](image-url)
processes and how learners attend to, manipulate and remember information during learning. Cognitive education in the teaching and learning process encourages learners to think and analyse a particular topic in gradually more complex ways (Krause, Bochner, & Duchesne, 2006). The Bloom/Anderson taxonomy is a hierarchical model for cognitive learning objectives, ranging from lower levels of learning (i.e. knowing and understanding) to higher levels of thinking, which involve of the synthesis, evaluation and analysis of content. The taxonomy consists of six major categories including Remembering, Understanding, Applying, Analysing, Evaluating, and Creating (Anderson, et al., 2001). The first three categories require a good deal of involvement and scaffolding from teachers, and focus on knowledge, comprehension and application. The other three categories are more sophisticated and involve higher order thinking by learners. These elements emphasise analysis, evaluation and creativity.

This study proposes a new educational framework for designing mathematics multimedia software, which captures all elements of the Bloom/Anderson taxonomy (Figure 2).

The educational framework of cognitive learning objectives, which draws from the Bloom/Anderson taxonomy, also influenced the instructional design process of this project. Various educational objectives and techniques based on cognitive learning theory, such as breaking information into small parts, memorising content and practising, storing and retrieving information, were applied to the instructional design process. Figure 3 illustrates the composition of the instructional design components, which incorporates cognitive learning theory based on the Bloom Anderson taxonomy, to shape and define computer-based instructional materials for assisting in teaching and learning mathematics in lower primary school.

**ADDIE comes to life: using the instructional system design principles to My Maths Story project**

The study aimed to design and develop computer-based multimedia application (software) based on a strong educational framework. With the underpinning educational framework, along with the capability of multimedia technology for presenting multiple representations, as well as the use of children’s literature for teaching mathematics, it was possible to design and develop two sets of interactive multimedia educational software named My Maths Story Tools 1 and Tools 2. The two sets of multimedia applications were designed and developed following the guidelines of the ADDIE instructional design model as a systematic approach to analysing the specific teaching and learning needs and the development of tools to meet the needs. The next section of this article discusses the design and implementation process of Tools 1, based on the ADDIE model, taking into account the educational framework components and trialling the developed tools in real world settings.

**Analysis**

As mentioned earlier, disconnections between theory for designing educational applications and theory concerned with applying

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**Figure 2.** The proposed educational framework of the cognitive learning objective
educational application for teaching in classrooms, coupled with a lack of alignment with curriculum and instruction to support learning, have been highlighted as main issues that can hamper the quality and relevance of existing computer-based educational applications. To overcome this problem, detailed analysis of the following areas took place within the analysis phase of the ADDIE model: (a) users’ needs and requirements; (b) target users’ characteristics; (c) pedagogical and learning objectives; and (d) subject matter and design, along with the establishment of instructional goals and objectives.

Analysis of users’ needs and requirements: The researcher investigated and identified Australian mathematics teachers’ needs and their classroom requirements through a range of activities, including:

- Interviews and discussions with teachers and mathematics educators about designing a new software based on mathematics classrooms’ needs;
- Review of literature and direct observation in classrooms to ascertain limitations of existing mathematics software;
- Observation of mathematics activities (computer-assisted and non-computer-assisted) in classrooms;
- Identification and examination of some of the preferred computer-based educational applications used in Australian primary school classrooms;
- Study of mathematics pedagogies in early childhood and lower primary;
- A review of the Australian Curriculum - mathematics;

These activities helped the main researcher (who is not a trained primary teacher) to understand the needs of teachers and children in Australian classrooms in relation to the teaching and learning of mathematics.

Analysis of target users’ characteristics: Junior primary school teachers and children (K to Year 4) were the main target users of this study’s multimedia software. Teachers’ experiences in using computer based applications and their beliefs and acceptance of using new technologies as teaching tools were varied. A range of technology skills among participating teachers, as main target users of the new multimedia software, was noticed through an analysis of teachers’ characteristics. Learners (primary school children), as the second main
target users, were not a homogenous group either. However, a great deal and knowledge of technology skill was not expected from children of such a young age. Almost all children in this age group could click, drag and drop an object by mouse or on a touch screen. It was found that children attitude and acceptance of using technology was generally positive. The target users' characteristic analysis informed the design and development process of the new application to ensure that the final tools meet the needs of all target users.

Analysis of pedagogical and learning objectives: Clear pedagogical and learning goals and objectives are an essential element of any multimedia application design (Frey & Sutton, 2010; Gagne, Wager, Golas, Keller, & Russell, 2005). Pedagogical objectives can be described as what students will be capable of doing after the lesson or sequence of lessons (LeLoup & Penterio, 2003). Goals and objectives need to be specific and align with the curriculum with a clear outcome. Number and Algebra, Measurement and Geometry and Statistics and Probability are three content strands in the Australian mathematics curriculum. The first strand, Number and Algebra, contains four sub-categories including: number and place value; fractions and decimals; money and financial mathematics; and patterns and algebra. The broad learning objective of the study was to design and develop a multimedia application that teachers could integrate in their classroom to teach the Number and place value sub-strand of the Australian curriculum.

Analysis of subject matter: Subject matter analysis defines the content that needs to be included in the teaching and learning process (Anderson, Rourke, Garrison, & Archer, 2001), which is directed by the pedagogical and learning goals. Part of subject matter analysis involves searching for optimal resources. As mentioned earlier, using children’s literature is an effective approach in mathematics education for young children and was acknowledged (by participating teachers and mathematics educators) as an appropriate and accepted teaching method in Australian mathematics classrooms. Based on a review of existing mathematics concept books and discussions with teachers and other mathematics educators, an engaging mathematics concept book, “One is a Snail, Ten is a Crab”, a counting by 'feet' book written by April Pulley Sayre, Jeff Sayre, and Randy Cecil (2003) was selected. This picture book is about counting animals with various numbers of feet; e.g. “5 is a dog (with 4 feet) and a snail (with 1 foot)”. With permission from the publisher, this book was used as a basis of the multimedia software in the My Maths Story-Tools 1.

Design

The data from the analysis phase provided important information to support decisions in the design stage. This information was used to assist in the identification of areas where multimedia might add value in mathematics teaching and learning.

The proposed educational framework, which captures all elements of the Bloom/Anderson taxonomy, was used as a guide in selecting and designing instructional strategies to address the teaching and learning goals and objectives. This study applied a range of instruction strategies to capture all levels of the proposed framework through the use of multimedia technology. The instructional strategies used were: Explicit Teaching, Fluency Building (Skill Building) and Problem Solving and Peer Partner Learning. The multimedia educational tools contained three components, which applied all elements of selected instructional strategies at different levels of the conceptual framework, including: (1) Interactive Storybook software; (2) Students Activity software; and (3) Group Project software.

Interactive Storybook software: Storytelling or using children’s literature is the first level of the educational framework (lower section), where the whole class can be engaged. However, teacher involvement (scaffolding) to focus children’s attention on the story and the embedded mathematical concepts and the building of comprehension is substantial at this level. Through storytelling and the use of elements of the chosen mathematics concept storybook (e.g. characters, scenes, numbers, words), the areas where multimedia (e.g. image, text, sound, audio, animation) might add value in the mathematics teaching and learning in an engaging ways were identified.

The first component of this study’s educational tools, Interactive Storybook software, was based on the instruction strategies in the described sequence through, explicit teacher modelling and scaffolding instruction. As noted above, the “One is a Snail, Ten is a Crab” mathematics storybook is about counting animals with various numbers of feet and each page of the book focuses on particular number. For example, the first number is “1” and a snail (one of the characters of the book) always represent the number 1, because snails have one foot, while a person with two feet represents number “2”, and number “3” is represented by a person (with two feet) plus a snail (with one foot). The same theme was carried out in the software by presenting and focusing on a particular numbers through the use of multimedia technology. In the software, each page of the book was reflected as an individual screen and focused on introducing a specific number as well as ability to interact, modify and create a new story. Various media elements were identified to symbolise the particular number (multiple representations) in each screen, along with
ability for users (teachers and students) to create a new mathematics related story. Figure 4.a illustrates an early stage draft of the Interactive Storybook software’s design strategies.

Teachers can use the Interactive Storybook software to introduce, model, show or discuss many mathematics concepts related to the “Number and Place value” sub-strand of the Australian curriculum. The story can be read to children (by click on the Story reader icon) first, then teachers can introduce a particular number in multiple representations, including; visual, numerical, alphabetical and audio (counting by sound). Teachers can also manipulate the story through interactive elements on the software and ask children how, why and what questions. Children also can be active participants of the lesson by answering the teachers’ questions through manipulating, adding and removing objects on the screen.

**Student Activity software:** The second component of this study’s educational tools, **Student activity software** was based on building the skills of individual students through the use of knowledge and understandings already gained through the first level. This captures the middle level of the educational framework, which was based on the Apply category of the Bloom/ Anderson taxonomy.

The mentioned elements of the story (characters, scenes, numbers, worlds), media features as well as common mathematical symbols, such as plus (+), subtract (−), multiply (×), divide (÷) and equal (=), were used in the design of the Student Activity software, which encouraged the skill building (fluency building) through the drill and practice strategy (Figure 4.b). Through the elements of the Interactive Storybook software, teachers can introduce and demonstrate a specific subject then gradually move students to the second component to practise and memorise the taught concepts. For example, if the learning focus is on skip counting, the teacher can explain and model the concept through the Interactive Storybook software by creating different stories about skip counting. After children gain knowledge and understanding of the concept, teachers can use the second component for student individual practice and skill building. Through interacting, manipulating, and creating stories, students can practise their fluency skills by calculating answers, finding various answers and quickly recalling factual knowledge and concepts. Furthermore, students can receive immediate
feedback from teachers on their work and increase their acquisition of specific skills in the specific area.

**Group Project software:** The third component of the tools, named Group Project software, used the problem solving and peer partner learning instructional strategies. This is allied to the upper level of the educational framework, which is based on last three categories (“Analyse”, “Evaluate” and “Create”) of the Bloom/Anderson taxonomy.

This component contained all of the elements of story and multimedia used in the Interactive Storybook and Student Activity software. However, this component had an extra feature for recording children’s voices while they solved a maths problem individually, in pairs or in small groups. This is a feature to help teachers assess students’ mathematical thinking through verbalisation (thinking aloud) while solving a problem. Teachers can divide their students into pairs or small groups and pose a maths problem (e.g. mathematical word problem), with story elements providing motivation and context, and ask children to find solutions. Children’s conversations, reasoning and mathematical dialogue during problem solving can be recorded, saved in the computer and teachers can access this for analysis. The listening ability of children (verbal) and seeing the final solution to the maths problem on their workstation (computer screen) or printed paper (non verbal) will also provide important assessment information for teachers, including; children’s thinking and understanding by drawing on their previous knowledge, their ability to apply this knowledge to assist in finding a solution to the problem. Teachers can also identify children’s misconceptions and confusions relating to particular concepts through this process (Figure 4.c).

In the final stage of the design phase, a formative evaluation was conducted to gain feedback on selected instructional strategies, multimedia elements and subject matter. The designed components were presented to three lower primary school teachers and mathematics educators. Different pedagogical strategies, samples of teaching and learning activities and teachers’ and learners’ contributions were clearly explained during the presentation. Through this process, the tools were submitted to critical judgment before the decision was made to move onto the development phase.

**Development**

The development phase was based on the results of the analysis and design phase. Detailed information from the design phase provided guidelines for the development of the multimedia educational tools. The application, My Maths Story, was designed and developed by one of the researcher in a computer science lab. Through the development process, operational functionality, graphical elements, software interface, media production and testing were established. The components of the educational tools, including the Interactive Storybook software, Students activity software and Group Project software, which were designed in the previous phase, were created in this stage (development phase).

**Formative evaluation:** A substantial formative evaluation was conducted after executing the development phase and before implementation of the multimedia software in schools. For this purpose, the developed tools were presented to 32 pre-service teachers and 2 early primary mathematics educators at a university in Western Australia. Each pre-service teacher and mathematics educator assessed the application for approximately 25 minutes. Through this evaluation process, several technical issues were detected, for example the “Sweep” (Clear) button did not remove all objects in some pages. Pre-service teachers suggested modifications to some of the software elements such as: “It would be good to have a “replay” button for each numeric and alphabetic animation.” The survey and interview data were analysed and necessary changes were introduced to improve the tools. Once this process was finalised, the tools were considered ready to move to the Implementation phase.

**Implementation**

In order to demonstrate the value of the tools in facilitating mathematics teaching and learning, the tools were offered to five different primary schools in Western Australia. Three public, one private and one specialist school for English as Second Language students, from areas with different social and economic demographics, trialled the tools for approximately two school terms in 2012. Twelve teachers and 284 students in multiple grade levels (K to Year 4) used the tools in their classrooms for teaching and learning different mathematical concepts. The software applications were used in classrooms (on interactive whiteboards) for whole class engagement and in school computer labs (on personal computer and laptops) for individual and small group work.

Participant teachers used the different components of the application for teaching counting, place value, number sense, number relationships and basic addition for younger children, while they used it to teach skip counting, counting by sets of 2’s, 4’s, 10’s, even and odd numbers, addition, subtraction and multiplication in different ways for older children throughout the terms. Teachers created various interactive stories by choosing scenes, characters (e.g. a snail, person, dog, insect, spider, crab) and appropriate multimedia such as sound and text (figure 5.a) and emphasised the intended learning outcomes or objectives by explaining the scene, retelling, and asking ‘why’ and ‘how’ questions. This helped students to recall facts, terms and concepts by
remembering, describing and explaining (the "Remember" and "Understand" categories of the Bloom/Anderson model—lower level of the educational framework).

Through interacting, manipulating, and creating various stories, students practised their fluency skills by calculating answers, finding various answers and recalling factual knowledge and concepts readily (the "Apply" category of the Bloom/Anderson model—middle section of the educational framework) (figure 5.b). Teachers also used the Student Activity software to create various mathematics activities for their class students in different formats (print and interactive) (figure 5.c). The software was also used for teaching more complex concepts through teachers generating a story or a mathematics word problem and then asking students to analyse, explain and solve a problem individually or in pairs (the "Analyse", "Evaluate" and "Create" categories of the Bloom/Anderson model—upper level of the educational framework) (figure 5.d).

The researcher was consistently available and accessible to participant teachers to address technical and pedagogical issues and questions during the implementation stage. Towards end of the school term, individual and semi-structured interviews with the participant teachers occurred. Furthermore, teachers were asked to complete a questionnaire.

**Evaluation and Findings**

At the end of implementation phase, all data and information, which was collected through semi-structured interviews and questionnaires and observations, were saved and stored in a filing system for analysis in the evaluation phase.

*Technological evaluation: Interview and questionnaire results indicated that teachers were satisfied with the technical aspects of the software. They responded that the design elements and layout were clean, simple, consistent and well structured."

"I think the look and presentation is very professional and all my students found it very easy to use." Year 3 teacher.

"Like the clean layout structure of the software and available features, it is interactive and engaging." Year 2 teacher.

Teachers thought that it had been possible to present multiple representations of mathematics concepts creatively and clearly through the use of the multimedia components in the application. All participant teachers endorsed the flexibility permitted through being able to change and modify the software to address a range of
mathematics topics and to fit their students’ diverse needs.

“It [the software] is very flexible and open-ended; it can cater for many different skill levels in a classroom.” Year 4 teacher.

Easy to find and use multimedia elements, the ability to change and modify mathematics exercises to suit students’ skill levels, visual and graphical appeal (to children), and the ability to use it with an interactive whiteboard for whole class engagement, as well as its suitability for use individually or in pairs, were highlighted as advantages of the application by all participant teachers.

“In our school we are using the … (software name) software as our mathematics resource, which is based on individual learning, mainly assessment based, and children learn though trial and error. However, I found the My Maths story software is very flexible... because of the characters and story theme, you can create and tell a story and it makes sense to children, there is big difference between these two types of applications. It [My Maths story software] is not just trial and error, right and wrong... I can share ideas with my whole class, my students can use it individually, and we can create a small group activity, or work as pair on a problem.” Year 3 teacher.

However, teachers requested some new features for the development of future application such as the ability to move the text box around the screen or remove it from screen by dragging to “Sweep” button or the ability to change some of the story elements’ size (enlarging and minimising).

Pedagogical evaluation: In response to questions about their pedagogical beliefs and the teaching activities facilitated through the use of the application, teachers stated that they were able to use the software to demonstrate and explain targeted mathematical concepts to their classroom. They indicated that the presentation of mathematics concepts within a story in a multimodal way, and having the chance to choose pictures, audio and animation to tell the mathematics concept story, helped them to express various mathematics concepts much easier and faster than in traditional ways.

“This application has numerous uses for both teachers and students to generate [mathematics] ideas.” Year 2 teacher.

“Interactive and engaging way of introducing and explaining mathematics concepts.” Year 1 teacher.

“Some of my children have been struggling to memorise basic addition facts, for example, 6 and 4 always make 10... that was really nice way to explain the concept through presentation of picture of an insect (with six feet) and dog (with four feet)... seeing the characters of the story visually help them to memorise the fact in an engaging and fast way, whereas in the past, I usually sang a song or wrote over and over the fact with numbers and mathematic sign... I am going to use the software for explaining and modelling subtraction and take away concept next week.” Year 2 teacher.

Using children’s literature to explain the abstract concepts of mathematics also specified as an advantage of using the application in teaching and learning process.

“Number are abstract – that’s why children find it hard, but the story’s characters like snail, dog and spider are real...they can see it in their real life and connect with them straight away.” Year 2 teacher.

Many teachers reported that their students showed increased comfort levels in talking about their understanding of mathematics concepts through making their own story and sharing and discussing it in the classroom. Memorising and practising a mathematics fact and helping children build skills through motivational tasks, using the story’s characters, were mentioned as benefits of using the tools.

“I found, it [the software] helped my children to memorise number facts.... It was fascinating for me to see... (student name), working on basic number fact on her computer. I asked her to make “number 16” and she dragged and dropped a crab and an insect, then I asked her to make the same number in another way but do not use the crab... she quickly grabbed two spiders and said here are two group of eight that make 16. It was fascinating to see her doing and reasoning like that when, in the past, she had trouble in this area... it seems to me she was engaged in the story and memorised facts through using the story’s characters.” Year 1 teacher.

Modifying the original story by changing characters or settings, explaining the scenes, retelling the story, and asking ‘why’ and ‘how’ questions through variations of the story were highlighted as strengths of using the application in the classroom. Opportunities to interact with the familiar characters from the story in order to create mathematics exercises for various levels, and even for students to pose their own problems and find
answers individually, in pairs or small groups, were revealed as advantages of using the application.

“This week, I opened the software in the interactive whiteboard almost every morning. I created a maths problem, something as simple as, “Make number 19”. When my children came into the class, first they asked, “What is this?” and then they said, “Can we do it?” I let them to play and come up with different ways of making number 19 through using the story’s characters and counting feet... While they were doing this, I asked them to talk and verbalise the process and explain what they were doing to the class. Sometimes I stopped them and posed a question.... The next day, I made the problem a bit harder...” Year 2 teacher.

A unanimous agreement (100%) was seen among the participant in-service teachers and pre-service teachers in response to the question as to whether they would, in the future, use the multimedia software instead or alongside traditional books in their classroom. However, teachers suggested variations to the software, including the use of more mathematics language vocabulary and terminology, an increased number of characters, elements and story plots and the provision of hands on (concrete, non-digital) material based on the story’s character and themes.

Discussion and summary

The findings indicate that teachers were able to define and set certain mathematics pedagogical and learning objectives that aligned with the Australian Curriculum and use the multimedia application as a teaching tool to teach the planned objectives. Furthermore, the application offered teachers multiple opportunities for modelling, sharing and discussing a range of mathematics concepts within a story, in a multimodal way, and helped them to express various mathematics concepts to children in engaging and faster and deeper way than in traditional way. Also, the findings reveal that the software helped to activate students’ curiosity about mathematics topics, to engage them in the learning process, to interact with content, to keep them on task, to provoke sustained and useful classroom interaction and, in general, to enable and enhance their learning of the subject content individually and in pairs or small groups.

The ADDIE instructional design model was found to be a useful guideline for building effective teaching and learning tools. The formative evaluations during the various phases of the model informed the researcher to determine whether teachers and students would use the software product to reach their teaching and learning objectives, and how it could be improved before implementation in real world settings.

Conclusion

This paper has proposed that a lack of alignment between technology, curriculum and pedagogy in many existing mathematics computer-based applications is one of the main reasons underlying teachers’ rejection of mathematics software in Australian primary school classrooms. To address this problem, a theoretical framework, based on accepted pedagogical strategies by Australian primary teachers and educators, was used as a basis for the design of new software. The ADDIE instructional system design was used as guide the process of designing, implementing and evaluating the software. This paper has also described this process, as well as the findings of the My Maths Story - Tools 1 project. The findings indicate that the application, because of the strong theoretical and pedagogical underpinnings, did not share the limitations of many existing computer-based mathematics applications. The application appears to hold considerable potential for teaching mathematics in junior primary mathematics classrooms through storytelling and the use of multimedia technology to present multiple representations. However, teachers requested some new features, which directed this study to development of the second tools (My Maths Story-Tools 2), which will be discussed in a future paper.

References


For more details of the educational theoretical framework please see another publication by authors: Moradmand, N., Datta, A., & Oakley, G. (2013).

The principle of lateral innovation, originally posited by DeBono (1968), suggests that design should stem from the generation of new ideas and approaches, without regard to order or sequence (Barak & Doppelt, 1999; Waks, 1997). With games, today’s cost of building such systems is massive, running into the tens of millions of dollars. Multi-platform game generation is even more expensive, requiring as much as $28 million (Crossley, 2010).

Over the last decade, grant funding organizations at the federal, state, and foundation levels have spent millions developing games, multi-user virtual environments and other innovative systems with life-like graphics, sounds, and interactivity. These have included the National Science Foundation (NSF) funded River City (Dede, Ketelhut, & Ruess, 2006), Quest Atlantis (Barab et al., 2007), Whyville (Kafai, Quintero, & Feldon, 2010), TERC’s Blue Mars world Arcadia (Asbell-Clark et al., 2011), and Citizen Science (Gaydos & Squire, 2010). Other funding has come from the National Aeronautics and Space Administration (NASA) with CyGaMEs (Reese, in press) and the MacArthur Foundation to study game-based curricula like Quest to Learn (Corbett, 2011) and literacy practices in games like World of Warcraft (Steinkuehler & Johnson, 2009).

Research on educational game systems has been correlated with a number of learning-related outcomes. These include improved student motivation to learn (Tuzun, 2004), better understanding of historical concepts (Squire, 2004), increases in student writing scores (Warren, Barab, & Dondlinger, 2008; Jones & Warren, 2010), increases in knowledge acquisition (Jones & D’Alba, 2012), and understandings of complex science concepts (Barab, et al., 2007; Dede, et al., 2006; Foley, Jones, & McPhee-Baker, 2002; Kafai, et al., 2010). In addition, these systems have been shown to improve student situated identity and social empathy (Barab et al., 2009; Foster, 2008; Gee, 2004) in the context of science learning. However, these gains are not without question in terms of their transfer from the game itself to formal classroom and other settings as well as the

Overcoming Educational Game Development Costs with Lateral Innovation: Chalk House, The Door, and Broken Window

Scott J. Warren, University of North Texas
Greg Jones, University of North Texas

Abstract. Over the course of the last decade, the idea of using games to support student learning has become increasingly accepted in academic circles as the next breakthrough for improving learning. However, the costs of developing games for learning can be prohibitive, with commercial game development running in the millions of dollars. In order to build low-cost educational games, we have proposed an alternative design method that leverages older, widely available technologies called Re-Examination Theory. This article presents three cases in which this theory has been leveraged to develop and implement educational games in both the K-12 and post-secondary settings.

Keywords: Re-examination; Chalk House; The Door; Broken Window; problem-based learning; literacy; research; models; low-cost; alternate reality games
research methods, sample sizes, and populations drawn from, as noted by Clark (2013) and Hays (2005). Warren and Lin (2012) also identified additional challenges in terms of the ethics of using complex games with children and other protected populations, when the likelihood of confounding factors such as direct teacher instruction in much of the research done to date, makes it difficult to make the claim that the game itself was responsible for learning. With these caveats in mind, we believe that educational games can and have impacted learning and as additional tools allow researchers to parse data more cleanly, we will better understand the specific benefits of these games that may have been previously undetectable.

**The Cost of Educational Games**

However, while such promising research results bear further study, projects supporting educational games are often funded with millions of dollars in government funding. However, those that wish to use or design games for education are faced with limited possibilities for funding such systems, especially in an economic and political environment in which federal grant funding continues to decline or remain stagnant from 2010 and 2011 levels (Mervis, 2011). This makes employing the technologies and accompanying designs difficult for the average academic or instructional designer. The high-end graphics, long development times, and large design staff available to well-funded projects allow for development of game systems closer to what game companies are developing for commercial entertainment uses, though still fall well short of their high-end cousins. Further, research in the area of graphical fidelity, or how closely a game or simulation represents reality, indicates that high visual fidelity to the real world is not necessary for learning, instead, it is the fidelity of the activities that are important (Malamed, 2009).

**Re-examination Theory.** Since high levels of funding are not normally available to educators interested in designing and building learning games, we must examine what is ideal and what is possible when deciding whether to use learning games and which tools will best meet the learning goals we set forth. As researchers and designers with a limited budget, this first led us to theorize that there are principles for designers to follow in considering older technological design tools for educational games (Warren & Jones, 2008). We have now leveraged this theory in three game designs that followed the process set forth in our Re-Examination Theory, which is an extension and re-contextualization of a theory held by Nintendo designer Gunpei Yokoi (Crigger, 2007). This article will first reiterate and refine that theory in the context of three game designs.

We will then explain how that theory translated into instructional design practices that supported the development of three games. The first is *Chalk House*, a 3-D adventure game designed to support middle school English literacy. The second is *The Door*, an alternate reality game course for introductory computer science concepts. Lastly, we present the design of *Broken Window*, a blend of alternate reality gaming and student instructional game design to teach core computer literacy ideas.

**Theoretical Framework**

**Games and learning**

Common theory regarding the use of games for learning comes from the area of motivation through play (Denis & Jouvelot, 2005; Gee, 2003; Kelly, 2005;Steiner, Kaplan, & Moulthrop, 2006). Knoetes (2010) hypothesizes that both intrinsic and extrinsic forms of motivation are necessary for encouraging students to engage in academic tasks either by using students internal need to succeed or through the punishment and reward aspects of a game. Another common argument, which we have also made (Jones & Warren, 2008; Warren, et al., 2008), is the idea that we should meet students where they are and, as “digital natives,” kids play games (Prensky, 2001). This argument has not found substantive support in the research, and contrarily, some work with alternate reality games for learning has indicated that students do not necessarily want instructors in their personal or entertainment spaces (Warren, Dondlinger, et al, 2011).

Beyond this, other designers and researchers have focused on the literacy practices found in games that players often engage in informally. Some of this work has especially focused on massively multiplayer online games (MMOG) like World of Warcraft and earlier, Star Wars Galaxies, can be leveraged to support student learning such as computational literacy (Squire & Steinkuehler, 2005; Steinkuehler, 2004; Steinkuehler & Johnson, 2009). By leveraging digital gameplay, students are expected to engage in activities that they may otherwise be unwilling to engage in academically. This argument by Steinkuehler and her co-authors (2004; 2009) for supporting student literacy practices best supports the work under discussion in this article. Specifically, all three games focus on student literacy practices through either direct instruction methods or social constructivist knowledge construction contextualized within play. However, the games under discussion here are distinguished by another factor.

**Yokoi’s Theory: Lateral Innovation of Withered Technologies**

The factor is that the core of the Re-Examination
theory that guided the design of these games comes from the mind of Gunpei Yokoi. Yokoi was a long-time designer of game system components for the Nintendo Company of Japan, currently well-known for its Wii game console and popular video game characters like Mario and Donkey Kong (Wikipedia, 2008). His most notable achievement was designing Nintendo’s highly successful Game Boy system. This evolved from his personal philosophy of design called “Lateral Thinking of Withered Technology” originally depicted in a book of interviews with the famed Nintendo game system designer called “Yokoi Gunpei Game House.” Lateral thinking is a non-linear, creative and critical thinking process that allows for multiple, often-innovative solutions to problems (Barak & Doppelt, 1999; DeBono, 1968; Waks, 1997). The term “withered” has negative connotations in some cultures; however, Yokoi merely refers to technologies that have matured to the point that they are inexpensive, understood by the general public, and require little training on the part of the user to be implemented easily (Warren & Jones, 2008; Wikipedia, 2008). By applying non-linear thinking to such withered technologies, his theory states that these mature tools can be employed in innovative ways and engage users without adding unnecessary product development costs.

What is important in this theory is that the novelty of the play and the interactions between player and system provide intrinsic motivation rather than having top-end graphics and high-end computer processor power (Crigger, 2007). By applying this philosophy to several game designs, it has been revealed that it is more cost effective to rely on older, proven technologies for design rather than bleeding edge technologies and he even went so far as to suggest that employing advanced technologies may interfere with designing innovative products because of excess focus on the technology rather than on the innovate use of it (Warren, Dondlinger, McLeod, & Bigenho, 2011; Warren & Jones, 2008). Further, the design and development time of educational games is reduced when applying lateral thinking about mature technologies than it is for “bleeding edge” products. This reduction stems from the fact that the relevant technologies are proven to work effectively even as they save both the developer and user money (Warren & Jones, 2008). In many educational settings, shrinking budgets and reduced grant funding are recurrent problems, as the world economy remains stagnant. How then can we leverage Yokoi’s theory in the field of education as we seek to design and develop games for learning?

Re-Examination Theory

In our own design and development practices, we have sought to leverage the use of lateral innovation in what we have called Re-Examination Theory, states that:

“educational games should avoid seeking bleeding edge solutions, and should instead leverage mature, disparate, and sometimes discarded technologies in innovative ways that stem from re-examination and analysis of the underlying learning affordances of these technologies, rather than relying on the development of entirely new systems” (Warren & Jones, 2008, p. 9).

The five basic principles of Re-Examination Theory seek to locate resource technologies for building learning technologies at a low cost with high reward. We have found that they are best considered in the following questions:

- Is it a mature technology?
- Is it widely available?
- Is it well understood?
- Is the technology inexpensive?
- Can the technology be used to develop innovative pedagogy?

From these basic principles, we have proposed a process for evaluating and examining older technologies to determine their usefulness for developing games today, which can be seen in Figure 1.

By “mature technology,” we refer to those that are widespread in use and that the majority of people are literate with such as word processing programs, drag and drop web authoring tools, web logs, Java-based design platforms that have existed since the mid-1990s, and other tools that may be closer to being retired in favor of those with more complexity or flashy graphics.

We have used this process of re-examination as way to determine which technologies are already abundant in specific education settings and then seek to use them in creative ways that challenge instructional designers to think differently about how things must be done. Designers should consider alternatives to the existing uses of well-known technology and instead seek to employ them in innovative ways to better engage learners by challenging them to act differently though cognitive challenge cognitively, rather than technological novelty (Warren & Jones, 2008).

Instructional design Methods

In this section, we detail three cases that leveraged Re-Examination Theory in order to design and develop digital learning games. These have included games that employ this theory to target traditional forms of literacy (i.e. reading and writing), computer literacy, and new media literacies. Throughout this section, we note lessons learned as a result of our instructional design experiences that may be used to guide other seeking to design their own low-cost games.
Literacy Games

Each of these games had different learning goals within the broader field of literacy, both as traditionally conceived by theorists such as Krashen (1989, 2004) which is, approximately, the ability to read and write printed text and has recently been conceived now by Steinkuehler in the context of games. She borrows from Gee’s concept that literacy discourses are the manner in which “humans integrate language with the non-language “stuff,” such as different ways of thinking, acting...using symbols, tools, and objects...so as to...give the material world certain meanings (Gee, 1999 in Steinkuehler (2008, p. 623).” Steinkuehler explains that “big D discourses” are Wittgenstein’s (1968) “ways of being in the world” and are “(t)he social and material practice of a given group of people associated around a set of shared interests, goals, and/or activities...these practices include shared discursive resources such as word choice and grammar...and other communicative devices involved in language-in-use (e.g. text conventions for prosody, gestures, or emotes); (and) shared textual practices for both production and interpretation...(such practices function as the observable means with which individu-
als display their membership within a given Discourse (sic) community and others recognize them as such. (Steinkuehler, 2008, pp. 623-624)."

Steinkuehler’s conception of developing literacy practices is akin to Lave and Wenger’s (Lave & Wenger, 1991) idea of developing communities of practice around shared activities in which new understandings are constructed through discourse and engagement in some form of work. These activities have been hypothesized to be important for learning, regardless of content area (Barab & Duffy, 2000; Barab, Warren, Del Valle, & Fang, 2006). In the cases of the three games presented here, each supports either the acquisition of the ability to read and write texts (Chalk House) based on past work in this area (Warren, et al., 2008; Warren, Dondlinger, Stein, & Barab, 2009) or the construction of new literacy practices in the area of computer literacy (The Door and Broken Window) through discourse centered around solving real world problems.

**Research Methods**

The research methods employed for the study of these designs stems from case-based research as framed within a design-based research framework in which each design is linked and one influences another through the research findings of the previous. The design-based research method was chosen, as the implementation of these designs is part of a longitudinal study of the use of learning games. The goal of these activities is to improve the design and use of learning games with several different populations of learners.

**Design-Based Research**

Exchanging the use the three learning games, data was drawn from a number of sources available as a result of the course’s technology-intensive nature. In keeping with Barab’s (2006) conception, design-based research,

“use(s) the close study of a single learning environment, usually as it passes through multiple iterations and as it occurs in naturalistic contexts to develop new theories, artifacts, and practices...(thus), the design-based researcher must demonstrate local impact, at the same time making a case that this local impact can be accounted for in terms of the particular theory being advanced (Barab, 2006, pp.153-154).”

The iterative design of each game, with content designed primarily by one lead designer, leverages systematic research findings from each game. This process follows Shavelson, Phillips, Towne, & Feuer’s (2000) concept that researchers must examine significant questions, link research to theory, make explicit one’s reasoning from one report to the next, provide data and methods for external critique, and use inquiry methods deemed credible by the larger community of researchers. It is from artifacts and research findings from the design-based research process that findings are drawn and influence the cycles of design and revision as we sought to improve benefits for learners.

**Data analysis**

Analysis examined digital documents, audio captures, text reflections and participant informal interviews. Each was identified as helping researchers understand and evaluate each iterative cycle of the games and helped create linkages among them towards building general design principles for learning games. Computer-mediated discourse analysis was conducted according to methods described Herring (2004). Analysis within Herring’s methods for examining qualitative themes followed a process proposed by Robson (2002) that included:

- Start with a research question
- Sample your documents from the general population
- Choose a recording unit
- Construct categories for analysis
- Test coding on samples of text and assess reliability
- Carry out the analysis
- Check for errors
- Compare findings

It is in this last step that we employed constant-comparative analysis as described by (Robson, 2002). Through this process, we coded feedback from students as contained in blogs and interviews to determine the effectiveness of each in terms of satisfaction with the instructional delivery. These codes were placed into larger categories and from these categories themes emerged. These themes are framed in terms of recommendations emerging from each design and design revision. In order to contextualize these, we also provide detail regarding each learning game design.

**Findings**

As a result of our analysis, a number of findings and recommendations have emerged from each of the three games: Chalk House, The Door, and Broken Window. While each had a different literacy focus, the implications from each are generally relevant to learning game construction. Further, each design followed Re-Examination theory and lessons learned are applicable regardless of content area a designer may seek to address.

**Chalk House: Gaming for Traditional Literacy**

Chalk House is an online computer-based 3D environment in which game play, engaging narrative, and
intelligent agents are used to improve student literacy skills (CRG, 2007). In 2009, in the United States, only one-third of students at 4th and 8th grade were rated proficient on the National Assessment of Educational Progress (Education, 2010). For 2007, students at 8th and 12th grade rated proficient showed no significant gains since 2002 (Education, 2008). The design was based on an earlier game space, Anytown (Warren, et al., 2009). The Anytown design was correlated with statistically significant improvements in student writing scores, voluntary writing activity, and a reduction in the amount of time the teacher spent scaffolding student learning (Warren, et al., 2008). However, the researchers noted structural challenges to the use of the game from both the school itself such as limited time in the school day for educational game use and pedagogical epistemic constraints on the part of one or more participants in the study (Warren, et al., 2009). Further, the study reported no findings related to student reading achievement scores (i.e. vocabulary use, reading comprehension).

As part of his design-based research agenda, one of the authors of this study worked to develop another version of the game that addressed the limitations of the original Anytown study and research design. In response to these findings and others, the audience for this game is middle school students (ages 10-14) commonly resistant to traditional reading and writing classroom activities (Goldberg, Russell, & Cook, 2003; Marshall, 2002). The game leverages the genres of mystery and ghost stories as part of its attempt to match with student interest.

The original design goal for Chalk House was to address school day limitations by creating 25 hours of reading and writing content to be used in a formal learning setting. Through this educational game, the instruction seeks to remediate student literacy skills either before or after their testing so that they can improve their language skills. Chalk House immerses students in an authentic writing role, a newspaper reporter, assigned to unearth the mystery of a purportedly haunted mansion in which several victims have disappeared. Numerous puzzles, linguistic challenges, and game structures place students in a world where assessment emerges naturally from their interactions with characters and environment, with the goal of leading students increased engagement with reading and writing (Jones & Warren, 2007; Warren & Jones, 2008). Figure 2 shows an example of the level graphics from Chalk House.

Figure 2. A view of Chalk House within the Created Realities Framework.
Before Chalk House development began, designers employed the theory of lateral innovation to generate new ideas and approaches to ensure that the product would fit the needs of the target group and at the same time derive a process to reduce the overall cost of development. As the group engaged in lateral thinking about the technology needed to support school use of the system that would drive Chalk House, a framework emerged that dictated that the game would 1.) operate under Windows, Macintosh, and Linux operating systems, 2.) require minimal of hard drive space, bandwidth, and computer memory, and 3.) deliver 3D graphics capable of being displayed in the majority of schools in the United States today. As a result, Chalk House has been completed in a 14-month period and deployed into schools for testing at a fraction of the cost of development of similar educational 3D online environments, requiring only $1,000 for server hardware, free software development kit, and programming, scripting, and other offline work done by project volunteers over the course of fourteen months. The following table presents the costs of the aforementioned games Chalk House, The Door, and Broken Window in comparison with a projection of games from a commercial designer and two grant-funded game projects, Anytown, which was part of the Quest Atlantis, and a second, Ted Castranova’s Arden: The World of William Shakespeare.

As presented in Table 1, it is evident that the main costs of those games following the low-cost methods result mainly in a cost of time on the part of those working on the games as volunteers. However, due to the widespread lack of reporting of the actual costs of development, it is difficult to provide an absolute picture of cost outside of those games we have designed ourselves. However, the following sections report some of our preliminary findings and associated lessons based on our models and publicly available information about commercial and some grant-funded projects.

**Lessons**

**Lesson 1: Leverage Existing Classroom Tools and Technology.** Designing software to run in a classroom must take into account certain physical and logical constraints. Elements such as computer operating systems, memory, graphics cards, and especially existing software tools being used for other activities. The CRG framework had already chosen its development to reflect current availability of computer technology found in schools. The CRG framework uses Java™ as the underlying programming language, first released to the public in 1997, having existed since 1991, making it widely available, stable, and known to the average user. This allows the CRG client to run on a variety of operating systems including Macintosh and Windows. Java’s™ computing performance several years ago made it an unlikely choice for developing a real-time multi-user online game. However, upon re-examining it today, the combination of improved computer performance, pervasive use on multiple computer platforms, and Java’s™ better operating characteristics make it a good choice for educational game design. Microsoft Word and other tools and similar open source versions are commonly found in computer labs. These tools are used outside of the client for the student to create materials that are then incorporated back into the game. This allows a teacher to specify tools available at their schools and also reduce the requirements to support these functions within the software.

**Lesson 2: Game as experience not game as engine.** The expense of providing video graphics found in many current games was well outside the budget of development. Therefore, the group had to focus on the game experience in order to make up for the lack of an advanced graphical user interface (because most schools don’t support the necessary graphics processing power). This meant that more time had to be spent on the design and creation of game interaction and overall game experience. This also means that different requirements have to be met for the best graphical experience that can be provided for the level of graphics most likely available in schools, which are not the blazing fast ATI and NVIDIA graphics processing cards found on machines designed for gaming. In recent years, schools have increasingly moved towards VMware-based computer labs that remove any capability for high-end graphics on the student’s computer in the lab. The Door and Broken Window employed mainly web-based technologies that are work on machines running Windows XP from that are ten years old, but because of the authenticity of the experience, there was no need for high end graphical fidelity.

**Lesson 3: Employ inexpensive development tools.** The cost of development and prototyping had to be answered with The Door, Broken Window, and Chalk House due to limited or non-existent funding. When they are designed, most computer game companies have a group of people just working on tools and prototyping. Since we lacked these resources, we had to create a new set of less costly development and prototyping solutions. In the cases of Broken Window and Chalk House, we mainly relied on sketching out the game interactions in notebooks called a bible or codex in order to design the interactions, characters, layout, and what the game would feel like. This was followed by the paper construction of a card or board game to test these interactions.

In the case of Chalk House, because of the 3-D component, a 2-D simulator was developed using PHP and HTML. This allowed game design and interaction
to be developed before the more costly 3D environment was created. This allowed us to very quickly prototype, test, and modify in a much less expensive environment. The 2-D simulator also allowed the project to perform usability testing early in the design process (Jones & Warren, 2009). After the initial design was complete, we had a more accurate time cost prediction for the designers that would be required to move into the 3D environment. More importantly, it allowed for narrative and interactivity revisions to be completed using the inexpensive 2D processes before moving to the financially costly 3D development. Today’s tools such as Unity 3D are further decreasing the expense and difficulty of rapidly developing educational games. This should increase the number and quality of educational games being tested or marketed.

The Door: Discovering undergraduate computer literacy with an ill-structured game

Another attempt to build a game using Re-examination Theory was in the service of redesigning an undergraduate course to support learning basic computer concepts such as the use of word processors, spreadsheet programs, and the website creation. In order to increase student learning through the perceived motivating power of games, the designers blended problem-based learning as conceived of by Savery and Duffy (1995) and game structures as depicted by Salen and Zimmerman (2004). A fuller accounting of The Door research findings can be found in Warren, Dondlinger, Jones, and Whitworth (2010) or Warren, Dondlinger, McLeod, & Bigenho (2011); however, the focus of this description is on how our theory was used to design and develop the game.

Low-cost design of The Door alternate reality game. Instead of producing the game within visual digital spaces like 3-D and 2-D games, alternate reality games (AltRG) are those that leverage the distributed resources of the Internet to produce a player experience that is slightly off of the real world (Dondlinger & Warren, S. J., Barab, S., & Dondlinger, M. (2008). A MUVE towards PBL writing: Effects of a digital learning environment designed to improve elementary student writing. Journal of Research on Technology in Education, 41(1), 113-140. A fuller accounting of The Door research findings can be found in Warren, Dondlinger, Jones, and Whitworth (2010) or Warren, Dondlinger, McLeod, & Bigenho (2011); however, the focus of this description is on how our theory was used to design and develop the game.

Table 1. Comparison of approximate costs among select learning games

<table>
<thead>
<tr>
<th>Game</th>
<th>Grant Funded?</th>
<th>Commercial?</th>
<th>Hardware cost?</th>
<th>Software cost?</th>
<th>Cost includes hosting?</th>
<th>Personnel cost</th>
<th>Total time</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalk House*</td>
<td>No</td>
<td>Yes</td>
<td>$1,000</td>
<td>$0/ Programmed/Blender 3D</td>
<td>Yes</td>
<td>3 volunteer personnel</td>
<td>14 months</td>
<td>$1,000</td>
</tr>
<tr>
<td>The Door*</td>
<td>Yes</td>
<td>No</td>
<td>Used existing</td>
<td>None</td>
<td>N/A</td>
<td>$300 for two volunteer graduate student travel awards</td>
<td>4 months</td>
<td>$600</td>
</tr>
<tr>
<td>Broken Window*</td>
<td>No</td>
<td>No</td>
<td>Used existing</td>
<td>None</td>
<td>N/A</td>
<td>1 volunteer $0 Graduate student and programmer salaries/@ $40-50,000</td>
<td>2 months</td>
<td>$0</td>
</tr>
<tr>
<td>Anytown**</td>
<td>Yes/Indirectly</td>
<td>No</td>
<td>Used existing</td>
<td>$1,450 yearly for Active Worlds support plus $395 startup</td>
<td>No</td>
<td>@ $45-55,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Serious Games***</td>
<td>Yes</td>
<td>Some are</td>
<td>Unknown/Depends on server size and other equipment</td>
<td>Ranges From $1,400 for Flash to $1,500 for Unity</td>
<td>No</td>
<td>3 to 15 personnel salaries</td>
<td>5-8 months</td>
<td>$54-135,000****</td>
</tr>
<tr>
<td>Arden: World of William Shakespeare</td>
<td>Yes</td>
<td>No</td>
<td>Unknown</td>
<td>Unknown</td>
<td>No</td>
<td>@ 3 graduate student salaries</td>
<td>@18 months</td>
<td>$250,000</td>
</tr>
</tbody>
</table>

* Follow Re-examination theory
**** Translated from Euros at €1 to $1.35, the exchange rate on 9/26/13.
This means using the “stuff” of the Internet such as e-mail accounts, wikis, web pages, Podcasts, YouTube videos, Twitter feeds, blogs, and other free resources for developing and implementing the game attributes. Instead of walking through a 3-D environment as with the Chalk House example, players encounter the learning context in the form of a story that generates the learning activities in the form of ill-structured problems. Instructors acted as facilitators or a “Puppet Master” rather than as provider of knowledge. They had resource of a 40-page job aid that guided them, role-play acting directions, weekly structures, due dates, and rubrics for evaluating student work. In The Door, the problems were posed by contacts with fictional characters played by the instructor. Each character communicated using e-mail addresses, messages left on blogs, and in secret codes (Warren & Dondlinger, 2008) such as in the Figure 3.

Throughout the semester, students engaged with these problems and are required to use the computer tools in order to produce solutions to each. It is in this way that the problems and activities are contextualized or anchored according to principles of situated cognition (Brown, Collins, & Duguid, 1989; Cognition and Technology Group at Vanderbilt, 1994). Further, because there is no one correct answer to the ill-structured problems, students worked in small groups to produce solutions and, along the way, engage in computer mediated literacy practices using the communication tools they were expected to become proficient with ranging from e-mail, text messaging, instant messaging, and online chat. As students learn to communicate with these tools, they construct their own discursive practices centered on the activities of learning to become computer literate. This version of the course game ran from 2007 to 2009 and the student experience and outcomes, as collected in their artifacts and blog reflections, shifted each semester as students and instructors constructed shared understandings in response to the needs of individual students and the manner in which the instructor responds to those needs with the evolving story. As a designed structure, The Door finished because alternate reality games are linear stories that, as with all narratives, have an end. One of the major findings with The Door was that students required more to do with the knowledge they constructed or acquired during their gameplay. Thus, Broken Window was the next evolution.

Figure 3. Distributed resources used by characters in The Door for game learning.
Broken Window: Computer literacy in game experience and student game construction

The Broken Window AltRG was developed during the spring of 2009 and implemented as a pilot for the first time in the summer of that year. The design goal of the new structure was not to deviate from the computer literacy focus of The Door, but to leverage the alternate reality game concept to give students the experience of a game for learning as they internalized what they are and the core ideas of computer security and communication (Warren & Wakefield, 2013). Further, we sought to engage the undergraduates in basic instructional design themselves to use the tools they learned to produce games centered on the United Nations (UN) Millennium Development Goals for their peers to play and evaluate. This learning by doing model was influenced by concepts of project-based learning (Blumenfeld et al., 1991; Land & Zembal-Saul, 2003) in which students learn by creating.

As with The Door, the resources that students would use were distributed across the Internet and a new narrative was created called Broken Window that would introduce students to the UN goals that included maternal health, environmental sustainability, and gender equality (Warren & Najmi, 2013). In this case, the game was distributed from two central locations: an open source content management system (CMS) called Joomla, a Twitter feed, and an associated blog through which the characters communicated the story and the ill-structured problems that students would solve. The Havenwyrd blog, created with the free WordPress tool is shown in Figure 4.

The Broken Window alternate reality learning game component ran for the first six weeks of each semester over the course of two years. It was moderated by all the instructors involved in teaching sections of the course, role-playing each character, and posting relevant resources to the open source Moodle learning management systems (Warren & Lin, 2012). It was within these that students turned in work and accessed additional resources provided in response to student challenges.

Figure 4. The blog through which Broken Window’s narrative emerged.
Conclusion

By focusing too much on the media creation (e.g., video games, simulations, virtual environments), we often fail to generate strong, replicable instructional game designs, distracted by the need to compete with the beauty of high resolution graphics. It is important to note that, over the last forty years, there have been a lot of costly, difficult to play games and simulations on the market. Some have failed commercially and become laughing stocks in mainstream media. This stems from the fact that they do not complete their task of entertaining well and the underlying system structures make them unusable. With Chalk House, we sought to generate an instructional game design that did not use “bleeding edge” technologies that may dramatically raise the overall cost of the product, limiting its reach. This was done with the idea that it is possible to move forward learning game design by developing and implementing a product that takes into account the budgetary constraints faced by many of today’s educators. This approach should be important to the field if we are to successfully leverage the underlying affordances of games: interactivity, motivation, narrative, and play.

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A Design Framework for Enhancing Virtual Team Learning

Jeanette Andrade, University of Illinois
Wenhao David Huang, University of Illinois

Abstract. This paper builds on existing theoretical and empirical studies in the area of virtual team learning in the workplace. Based on prescriptive theory building for instructional system design, a design framework is proposed to include social presence, swift trust, and conflict attribution components to enhance virtual team learning. This design framework intends to augment existing instructional system design models that are lacking emphasis on social and affective processing during virtual team learning in the workplace. Proposed implications for the use of this framework, suggestions for further research, and limitations of the design framework are discussed.

Keywords: Virtual teams, social presence, trust, conflict

Introduction

Workplace learning enables employees to gain appropriate knowledge and skills to improve their job performance. Team learning is a critical component of workplace learning. Teams often are the units of the operation to solve problems and to acquire and share knowledge in order to optimize their performance on tasks (Bennett & Bierema, 2010). For team learning to occur, however, the organizational environment needs to provide adequate learning opportunities for all team members (Clarke, 2005). To create such supportive workplace learning environments, organizations have adopted instructional system design (ISD) to help members of the team gain the appropriate knowledge and skills (Tennyson, 2010). As technology advances and globalization expands (Orlikowski, 2008; Watson-Manheim, Chudoba, & Crowston, 2012), organizations are facing new challenges to ensure that workplace learning environments can efficiently afford the intended learning processes for their employees who are increasingly becoming members of virtual teams. As Lepsinger and DeRosa (2010) indicate, as many as 50% of employees belong to some sort of virtual team within their organizations.

Various definitions of virtual teams exist within the literature and may encompass the following three components: 1) geographic distribution (e.g. different place, space, and/or time), 2) communication technological techniques (e.g. virtual spaces), and 3) completion of the tasks (Mesmer-Magnus, DeChurch, Jimenez-Rodriguez, Wildman, & Shuffler, 2011; Pazos, 2012). For the purposes of this paper, a virtual team is defined as collaboration amongst telecommuting employees that use various forms of technology to communicate and share knowledge in order to complete a task in a timely manner. Virtual teams are popular among organizations because they create collaborative environments regardless of physical barriers, allow for employee flexibility, and are inexpensive to organize as managers do not have to spend funds on travel and per diems (Guo, D’Ambra, Turner, & Zhang, 2009). Additionally, virtual team members who work collaboratively, out of necessity, are more likely to gain valuable knowledge to develop their expertise hence optimizing their performance (Ebrahim, Ahmed, & Taha, 2011; Liu, Magjuka, & Lee, 2008). Virtual teams as economical operational units in the workplace, however, are not without disadvantages. Two themes that repeatedly appeared in the literature are fragile trust and unresolved conflicts among virtual team members due to their inability to sense and create social presence within the virtual envi-
environment, which impacts the intended learning and performance outcome (Bennett & Bierema, 2010; Liu et al., 2008; Mesmer-Magnus et al., 2011). A viable solution, to overcome these limitations, is to facilitate team learning through the effective use of communication strategies within a virtual environment (Levi, 2014; Mayer, 2010; Mesmer-Magnus et al., 2011).

Communication strategies that have been noted to improve discussion amongst team members, for example, are social networking and virtual spaces (Ebrahim et al., 2011; Mesmer-Magnus et al., 2011; Schachaf, 2008; Warkentin, Johnston, & Shropshire, 2011). Schachaf (2008) discovered global teams that met in a team virtual space noted improvements in team collaboration due to the ability to socialize and share knowledge. Warkentin et al. (2011) reported that learning was enhanced if employees socially interacted with one another through social networking sites. Clearly frequent communication among virtual team members could encourage knowledge sharing that leads to learning and performance improvement in the workplace.

To entice communication among virtual team members, it is necessary to implement systemic and systematic approaches to align organizational interventions with intended communication outcomes. To do so, the ISD thinking should guide the identification of design solutions due to ISD’s capabilities to increase and maintain learners’ interactions with other learners and interactivity with the organizational learning systems (e.g., Hannafin, 1989; Sims, 1997).

Purpose of the Paper

ISD has been a necessary component when creating workplace learning environments to allow virtual team members to learn from anywhere and at any time (Rothwell & Kazanas, 2011). Prior research, however, has not clearly identified an ISD framework that can reduce virtual team’s limitations such as fragile trust and unresolved conflicts among team members to enhance workplace learning. The purpose of this literature review, therefore, is to devise a design framework that focuses on virtual team members’ opportunities to develop social presence, build trust, and resolve conflicts in virtual workplace learning environments.

The proposed design framework follows the process of building prescriptive theories commonly seen in developing instructional design theories and aims to articulate critical components of design in order to achieve the ideal state of activities in a focused area (Reigeluth & Carr-Chellman, 2009). In particular, the design framework centers on instructional resources that can afford virtual teams’ learning processes in the workplace. The following literature review sections will (1) synthesize literature on social presence, trust building, and conflict resolution, and (2) propose a design framework based on this synthesis that aids in facilitating virtual team learning and performance in the workplace. This proposed framework intends to augment ISD models in creating conducive virtual workplace learning environments that can support effective communications among virtual team members.

Literature Review

Social Presence Theory for Enhancing Social Presence

In virtual team environments, sensing the presence of one another may be difficult compared to face-to-face environments. In a face-to-face environment team members may see each other on a regular basis, thus ability to read each other’s verbal and non-verbal cues may become straightforward. However, depending on the system virtual teams are using to communicate, team members observing one another’s verbal and non-verbal cues may be limited (Cheshin, Rafaeli, & Bos, 2011; Gunawardena & Zittle, 1997). This hinders team members’ abilities to socially sense the presence of one another, which may lead to a situation in which learning and performance on the task is dampened (Montoya, Massey, & Lockwood, 2011; So, 2009). One theory, Social Presence Theory developed by Short, Williams, and Christie, explains individuals’ awareness to one another and the social interaction that takes place through telecommunications (Short, Williams, & Christie, 1976). They suggested social awareness can be achieved through two primary means: intimacy and immediacy. Intimacy depends on verbal and non-verbal cues such as eye contact and facial expressions (e.g., smiling). Immediacy is the physical distance between individuals and can be achieved through both verbal and non-verbal communications such as physical proximity and facial expressions. Social presence theory has been used to improve the design of virtual environments (e.g., virtual world) and as a result communication and learning amongst virtual team members has improved (Cheshin et al., 2011; Montoya et al., 2011; So, 2009). Focusing on enhanced communication within the collaborative environment, So (2009) discovered virtual teams that communicated on a frequent basis increased their sense of social presence and knowledge to improve their job performance. Montoya et al. (2011) discovered a collaborative virtual world environment increased the sense of social presence among virtual team members, which lead to improved communication and knowledge sharing. In summary, communicating frequently with team members in the virtual environment can enhance members’ ability to sense one another’s social presence, which has a cascade effect-learning occurs and performance improves. Moreover, if virtual team members have a sense of social presence, trust building may occur rapidly.
Swift Trust Theory for Trust Building

The benefits of virtual team members building trust quickly are immense as they would be able to share knowledge frequently and complete tasks (Sarker, Ahuja, & Kirkeby, 2011; Webster & Wong, 2008). Trust, however, is difficult to build in virtual teams for two reasons. First, communication among virtual team members is inconsistent. In face-to-face environments, it is easier to build trust than in the virtual environment because team members see each other physically, which may encourage them to communicate frequently (Kahi, 2008). By communicating frequently, team members are able to learn about one another both personally and professionally, leading to a trusting relationship that optimizes a team’s performance (Crisp & Jarvenpaa, 2013; Kahi, 2008). Second, communication among virtual team members is deficient in personal and social connections. In comparison with teams in face-to-face environments, virtual team members’ communication focuses more on work-related tasks than non-work matters. Without knowing virtual team members outside of the workplace, trust building would require more effort (Levi, 2014; Sarker et al., 2011; Webster & Wong, 2008).

The Swift Trust Theory developed by Meyerson, Weick, and Kramer (1996) is based on the notion that temporary groups are able to trust one another from pre-existing stereotypes as building trust via traditional means are limited. Mai and Raybaut (2010) expanded this theory to a virtual group. They created modeling systems to understand the relationship between trust, performance, and organizational feature (i.e. knowledge sharing). Their models indicated virtual community performance could be explained by the level of reliability or mistrust in the rate of individual participation, not necessarily by the pre-existing stereotypes held to form a swift trusting relationship. In other words, in the virtual environment swift trust occurs and is maintained through the life of the project by actions taken by individuals within the team (Xu, Feng, Wu, & Zhao, 2007). These actions are primarily achieved through informal knowledge sharing, completing tasks in a timely manner, communicating frequently, and respecting one another (Crisp & Jarvenpaa, 2013; Dube & Robey, 2008; Rusman et al., 2009; Sarker et al., 2011). Rusman et al. (2009) concluded that if virtual team members felt a sense of social presence and learned about different aspects of the project by communicating with each other frequently, trust could be built and lead to high quality performance. Sarker et al. (2011) concluded, at least for global student teams, trust mediates the relationship between communication and an individual’s performance. This essentially means if an individual has a high level of trust they will effectively be able to communicate, which will result in good performance. However, if an individual has a low level of trust they will not effectively communicate, which results in poor performance. Essentially, building a trusting relationship among virtual team members may also allow them to work collaboratively to resolve conflicts.

Conflict Attribution Theory for Conflict Resolutions

Conflicts arise in organizations due to misalignment among individual opinions and actions. Conflicts, however, are not all bad for the workplace (Liu et al., 2008). A typical conflict in a team would include two or more people, team members feeling a sense of struggle, latent participation among team members (i.e., some team members are not actively involved for many reasons), and various team members are powering over or attempting to influence decisions (Montoya-Weiss, Massey, & Song, 2001). Conflict tends to occur more often in virtual teams due to employees may feel a lack of social presence and a lack of trust (Kankanhalli, Tan, & Wei, 2006-7; Pazos, 2012). One solution to resolve conflict is via Conflict Attribution Theory (Kankanhalli et al., 2006-7). This theory proposes that teams can reduce conflicts through three ways: (1) Integrative (2) Distributive or (3) Avoidance. The integrative approach is when team members work collaboratively to resolve the conflict. The distributive approach is when a team member is charged to resolve the conflict of the entire team. The avoidance approach is when team members ignore the conflict at hand and move on. To resolve conflict in virtual teams, the integrative and distributive approaches appear to improve team performance as team members may discuss issues. In the avoidance approach, team members do not leave conflicts unresolved (Montoya-Weiss et al., 2001). Elhsan, Mirza, and Ahmad (2008) indicated that if virtual teams increase their communication via computer-mediated communication (i.e. e-mail and/or instant messaging), conflicts can be lessened and resolved. In investigating virtual teams and performance outcomes based upon conflict management, Pazos (2012) indicated that teams who actively work on preventing and solving conflicts as they arise improve their commitment towards the teams’ goals and ultimately performance on the task. In absence of shared trust and communication, however, conflict resolutions among virtual team members would be rather difficult if not impossible.

The Proposed Design Framework

The literature review serves as the foundation of an emerging design framework, the Social Presence, Trust Building, and Conflict Resolution (STC) framework. The framework synthesizes three theories to enhance the virtual team learning environment in the workplace: (1) social presence based on Social Presence
Theory, (2) trust building grounded in Swift Trust Theory, and (3) conflict resolution derived from Conflict Attribution Theory. See Figure 1 for the conceptual relationship among the three components.

The framework pictured in Figure 1 provides a solution to reduce issues commonly observed in virtual teams in the context of workplace learning. Specifically, this framework intends to increase trust level (swift trust theory) and to effectively resolve conflicts (conflict attribution theory) via increasing social presence among virtual team members. Based on past literature, the framework recognizes how improvement in communication within virtual team members could achieve the aforementioned objectives.

The STC framework follows the linear order of social presence, trust building, and conflict resolution. Social presence is a necessary component for virtual team members to trust each other and to collaboratively resolve conflicts as team members are able to feel that their peers are on the “same page” (Cheshin et al., 2011; Liu et al., 2008; Montoya et al., 2011; So, 2009). Additionally, social presence is the critical factor in improving communication effectively and efficiently and improves knowledge sharing among virtual team members. Trust building is the next in the sequence because if trust is built within the virtual team, then conflicts can be resolved quickly (Dube & Robey, 2008; Kankanhalli et al., 2006-7; Liu et al., 2008; Montoya-Weiss et al., 2001; Rusman et al., 2009; Sarker et al., 2011). Finally, conflict resolution is listed as the “outcome” component as it is built upon the foundation of frequent social presence and a trusting relationship among virtual team members (Dube & Robey, 2008; Ehsan et al., 2008; Pazos, 2012).

One ongoing process that needs to be present in order for the above framework to help virtual team members enhance workplace learning is frequent communication. Frequent communication is defined differently depending on the organization and the virtual teams’ task. A common acceptance is communicating on a daily basis at a specific time during the traditional eight hour work day via various methods (e.g. phone calls, instant messaging, google chats) (Mayer, 2010; Lepsigner & DeRosa, 2010; Levi, 2014). Frequent communication is defined here as communicating on a daily basis for a minimum of thirty minutes through the life of the project. To improve communication within virtual teams, the workplace learning environments should provide technological infrastructure such as virtual spaces (Ebrahim, Ahmed, & Tahan, 2009; Mesmer-Magnus et al., 2011; Schachaf, 2008), and social networking such as macro- and micro-blogging to improve communication and information sharing amongst virtual team members (Razmerita, Kirchner, & Nabeth, 2014; Reynard, 2013; Turban, Liang, & Wu, 2011; Warkentin et al., 2011). Macro-blogs allow team members to process the information and to collect their thoughts individually prior to communicating to the entire team (Reynard, 2013). This may be effective in the early stages of the learning cycle when individuals reflect upon the task at hand and then share their knowledge and expertise with other team members to complete the task successfully. Micro-blogging (e.g., Twitter or instant messaging), on the other hand, allows all team members to communicate on an ongoing basis throughout the life of the project (Reynard, 2013). This form of blogging may efficiently strengthen communication and knowledge sharing amongst the virtual team members. Furthermore, the structured system of social networking creates opportunities for virtual team members to sense the presence of one another, which tends to be a prerequisite for trust and resolving conflicts (Bente, Ruggen-
berg, Kramer, & Eschenburg, 2008; Reynard, 2013; Turban et al., 2011).

Other technological applications can be used to enhance the frequency of communication within virtual teams such as collaborative virtual worlds and game-based learning systems. Collaborative virtual environments, such as virtual worlds, are used to increase collaboration, communication, and knowledge sharing amongst virtual team members (Huang, 2013; Montoya et al., 2011; Raybourn, 2007). Virtual worlds are built to mimic real-life interactions and relationships among participants in various situations, which are useful for small (three members) or large (ten members) teams. Virtual worlds are essentially created to provoke group collaboration such that if all team members work together to solve problems and provide solutions, the entire team will move forward to reach the end goal (Montoya et al., 2011; Mueller, Hutter, Fueller, & Matzler, 2011; Thomas & Brown, 2009). Mueller et al. (2011) conducted a qualitative study with employees apart of virtual teams to investigate the current and potential uses of virtual worlds. Results indicated two reasons employees use virtual worlds are 1) the ease of building relationships and 2) the ability to trust team members due to the presence of avatars and ability to communicate frequently. Thus, virtual worlds may be able to assist virtual team members in completing their tasks within a timely manner.

Game-based learning is another collaborative virtual environment that has been used within organizations to engage and motivate employees in an attempt to expand their knowledge and improve communication (Huang, 2013; Raybourn, 2007). Game-based systems can be used in small or large organizations and can help virtual team members understand complex dynamics (i.e., medical triage teams learning how to be more efficient and effective within the field) (Knight et al., 2010). One such game-based learning environment is the adaptive training system, which can be used for single-user or multi-users (e.g. teams). For single-users, the adaptive training system orientates individuals to the system. During this orientation individuals learn how to navigate and communicate with others. Multi-user adaptive training systems allow virtual team members to learn about each other’s strengths and weaknesses and they are able to share problem-solving solutions and strategies (Raybourn, 2007, p. 207). This may lead to higher performance on the real workplace task at hand. Kutlu, Bozanta, and Nowlan (2013) conducted a study to determine the effects of team building in a virtual serious game. Results showed individuals were able to work together as a team as there was communication, a sense of presence, and they trusted one another. Organizations, however, need to consider many factors when employing virtual worlds and game-based learning for their virtual teams such as time to deployment, cost, data security, ability to support employees, and if these technologies would align with organizational goals (Montoya et al., 2011; Mueller et al., 2011).

The proposed STC framework should be considered as an auxiliary system to augment existing ISD models that lack considerations on virtual team members’ social and affective needs in workplace learning. In other words, the STC framework prescribes a specific set of design components to create instructional resources (Reigeluth & Carr-Chellman, 2009, p. 8) for virtual team members to enhance social presence, build trust, and resolve conflicts. The following section discusses the implication of the STC framework on the design of workplace learning for virtual teams.

Implications for Virtual Team Learning in the Workplace

Virtual teams are used frequently in organizations due to globalization and an increase of telecommuting employees (Orlikowski, 2008; Watson-Manheim et al., 2012). Therefore, learning challenges derived from social and physical limitations of virtual teams are emerging. Existing ISD models, while considering the attainment of learning outcomes, do not provide sufficient guidance to address virtual team learning issues such as fragile trust and revolving conflicts in distance; therefore, the proposed STC framework articulates design thinking beyond conventional ISD approaches. The implication of the proposed framework is twofold regarding virtual teams’ effectiveness in workplace learning. First, at the macro workplace learning system level, in addition to focus on the alignment among learning objectives, learning activities, and learning assessment, it is equally important to consider virtual team members’ needs on social presence, trust building, and conflict resolution efficiency. Second, at the micro learning system level, the STC framework articulates design thinking beyond conventional ISD approaches. The implication of the proposed framework is consistent throughout the entire workplace learning process to help virtual team members internalize desired communication patterns, trust building behaviors, and conflict resolution attribution into their daily learning tasks in the workplace.

Considering the STC framework’s role as instructional resources and the aforementioned implications, the framework should be primarily positioned in the learning environment analysis and instructional strategy development stages commonly seen in ISD processes (e.g., Dick, Carey & Carey, 2011; Morrison, Ross, & Kemp, 2004; Smith & Ragan, 2004). In terms
of learning environment analysis, the STC framework can guide the selection and integration of communication infrastructure to design a conducive environment to afford favorable communication and trust building activities among virtual team members. With regard to instructional strategy development, the conflict resolution of the STC framework in particular can support the rationale of including complex and authentic problem-solving opportunities for virtual team members to develop needed skills and understanding to interact with each other.

Limitations and Conclusion

Considering the five stages for theory-building in applied disciplines: conceptual development, operationalization, application, confirmation or disconfirmation, and continuous refinement and development of the theory (Lynham, 2002, p.229), the STC framework is only the first step (i.e., conceptual development) of a lengthy process. Among many limitations derived from the framework’s current developmental stage, we recognize two that are the most relevant to the next stage of design theory development. First, the STC framework, at its current stage, cannot provide tangible instructional strategies to specifically target certain STC components. Such outcome must be achieved by empirical studies derived from the framework. Second, considering the techno-centric context that enables virtual teams in the workplace, the STC framework might be inadequate for designing learning systems for face-to-face learning interactions. The conceptual synthesis embedded in the framework, nevertheless, could provide preliminary ideas to advance ISD theories and practices in today’s workplace learning that is saturated with technology-enabled teams.

References


Essay: Applied Instructional Design

Andrew S. Gibbons, Brigham Young University

“Applied” instructional design: what does the phrase mean? To some academics, applied evokes an image of the manufacturing floor: oily rages, smell of grease, blue lab coats, dirty fingernails, just production. There are no F-tests here, and no significance except that the product had better work when it rolls off the floor. It’s the term “applied” that conjures this false image.

Every field remotely related to technology (e.g., engineering, chemistry, physics, business, law, medicine, etc.) has a sub-field that uses “applied” in its name. Just pick the name of any academic field and Google it with “applied” attached and see for yourself. In Computer Science there are degrees in Applied Computer Science. In the social sciences there is a Society for Applied Sociology. For kicks, do this with “archaeology”.

What does “applied” mean in terms of practice? What does it mean in relation to theoretical issues? What does it mean for research?

The mission statement of JAID states:

The purpose of this journal is to bridge the gap between theory and practice by providing reflective scholar-practitioners a means for publishing articles related to the field of Instructional Design.

That’s pretty general. Does it refer to research articles? Development reports? Essays like this one? Opinion pieces? Technical Notes? There’s more:

JAID’s goals are to encourage and nurture the development of the reflective practitioner as well as collaborations between academics and practitioners as a means of disseminating and developing new ideas in instructional design. The resulting articles should inform both the study and practice of instructional design.

There’s the divide in our thinking between the “academic” and the “practitioner”. It would profit instructional designers to examine this gap in hopes of being more specific about the niches and habitats that exist within the world of instructional design and how designs evolve gradually to become artifacts.

Three years ago in this journal, Ellen Wagner (2011) addressed essentially the same issue in a slightly different way:

So I ask you this very pointed question—What do YOU think an ID should be able to do? Are we technologists? Psychologists? Evaluators? Programmers? DO we need business skills? Theoretical cognitive skills? Are we artists or engineers or a little of everything in-between? (p. 37, emphasis added)

If we are going to search for an answer to her question (and mine), we should agree from the start that there is not a single “right” answer. There is nowhere written in tablets of stone a formula defining the proper organization of work and skills and knowledge within a field of design—not even instructional design, which has fallen into some very inflexible and hard-to-change patterns. In fact, any observer today will readily recognize that there is really no such thing as a “field” of instructional design, except as people decide to call themselves instructional designers. We are not after truth here, rather utility, and it may be that the classical
categories Wagner names aren’t as relevant to progress as her “everything in-between”.

To illustrate this, I would like to relate some history from another technological field that provides food for thought about what applied instructional designers do. The setting is the tool steel industry, and the time period is roughly 1895 to 1905. Within this ten-year period a body of research performed in America revolutionized the world’s tool steel industry. It took the work of two unlikely actors working in a totally unconventional way in secrecy, trying to solve a problem of volume in steel production.

Frederick W. Taylor—who later gained fame as the efficiency expert who invented modern management practice—was hired in 1898 by Bethlehem Steel in Pennsylvania to solve a particular problem: production of ordinance (military) steel was experiencing bottlenecks, and output was unacceptably low. Taylor solved the problem, in a way described in detail by Misa (1995), as summarized below.

Taylor’s goal was making hardened steel cutting tools that could machine (i.e., mill, turn, cut, chip, plane, etc.) softer steel. This was a problem of bootstrapping, because as soon as you made harder steel, there had to be some steel even harder to shape, cut, and work it.

The financial implications of this problem clearly made it worth researching, but there was at the time no discipline of materials science; the scientific discipline of metallurgy was in infancy and had little to contribute. Steel making during this period was based almost entirely on received guild practices and expert-practitioner intuition, aided by tool concepts that were very old. There were few standards of practice or of product quality other than those taught by masters to apprentices. Though the steel industry was booming, there was great variability in the quality of the product, even within product categories, such as rail steel, or structural building steel. Railroad, bridge, and structural accidents were common.

One of the barriers to improvement of steel making practice was reliance on methods and processes that had been developed based on intuition and experience that evolved into tradition within an apprenticed system of steel makers. This body of “knowledge” evolved over decades without the benefit of systematic empirical study and measures and with only crude measures of process and product quality.

This tradition was completely contrary to the temperament and disposition of Frederick Taylor, who began a systematic study of how to make hardened steel with measurable qualities. Teaming with Bethlehem’s testing engineer Maunsell White, Taylor pursued a process of research that can best be compared to the recent phenomenon of design-based research (Kelly, Lesh & Baek, 2008; McKenney & Reeves, 2012). Today, in an industrial setting, this would be called “research and development”. The research proceeded in stages, each of which used a particular method, and each of which produced a certain kind of knowledge.

Taylor questioned the received wisdom about the amount of heat used in preparing hardened tool steel and the method of using the color of the steel during a melt for measuring progress. He heated one crucible steel melt to “bright cherry” and other melts to “dull salmon”, “salmon”, bright salmon”, and “yellow”.

This was not research based on a theory using a hypothesis: it was a fishing expedition. But it worked for Taylor, and the results were stunning. The lowest of the heats—bright cherry—produced steel of inferior quality, as the traditional wisdom would have suggested. However, Misa (1995) relates that, “received wisdom was shattered by the tools treated at the three highest heats” (p. 187). The higher-heat tools cut at remarkable speeds and for much longer periods of time. By “fishing” Taylor had been led into new, unexplored territory.

It is important to reflect on the difference in the nature of Taylor’s research at this point from the hypothesis-centered research instructional design students are directed to. Taylor was not proceeding in his research according to the dictates of a specific theory. In his own words he describes how:

This accurate practical heating and running of tools (without any theory on our part as to the chemical or molecular causes which produced the extraordinary phenomena) led to the discovery that marked improvements in the cutting speed…were obtained by heating tools up close to the melting point. (Quoted in Misa, 1995, p. 185, emphasis added)

Taylor not only demonstrated the existence of an effect, but with White he began to map out the unknown territory. Rather than acting like an explorer wandering through the west, noting a few impressive features, Taylor and White began to act more like settlers, with their surveying parties, mapping the terrain in detail.

Taylor’s measurement initiative and its instruments were a new cultural phenomenon in the steel mill, which had traditionally relied on visual inspections and subjective judgments by “experts” about the temperature of the metal as indicated by its heated color.

No wonder there was so much variability in the quality of steel. In the daytime, “bright cherry” might be the expert’s judgment; the same melt at nighttime might be declared “dull salmon”. Taylor realized that ambient conditions of light and weather influenced “expert” judgment of steel melt temperature. Therefore, he and
White implemented standard measures and standard instrumentation. A modified pyrometer (high temperature measurement tool), while it was somewhat temperamental to use with accuracy, surpassed the traditional visual inspection.

As the accuracy of temperature measurement went up, so did the consistency of the steel quality, and so precision increased. Multiple readings of a melt by multiple technicians using the pyrometer reduced the variability of measurements. As Misa (1995) reports, “the heat “light cherry” became the temperature 845°C, or 1,553°F” (p. 191, emphasis in the original).

Taylor added a second set of experimental variables at this point related to the cooling, or tempering, process of a melt. The new variables included cooling temperatures, timing, and quenching material used to bathe the cooling steel. By bringing temperature measurement and the variables of the tempering processes together under control, Taylor and White possessed the research process they needed for an extensive series of approximately 16,000 systematic studies conducted over roughly nine months. Their method was to manipulate the value of a single variable while holding all of the others constant.

This amounted to an enormous body of research. Rather than trying to confirm or disconfirm an explanatory theory, it sought to define the terrain of a previously unknown area of practice. This research was directly analogous to that of the Wright Brothers conducted only a few years later as they explored the best values wing and propeller shape for their aircraft (Combs, 1979). Ironically, both Taylor and White and the Wrights learned from their data that the received “scientific” guidance of tradition was flawed and had to be corrected through painstaking experimentation. This research did not just demonstrate the existence of a relationship, but rather it charted the full surface of that relationship as defined by the intersection of a number of variables and a desired outcome.

Taylor and White were successful at defining such a surface with respect to the application of their hardened tools to lathe work on steel. The full surface of this set of variable relationships was so well defined that Carl G. Barth, a member of Taylor’s research team, was able to construct a slide rule by which lathe operators could calculate for a particular piece of steel to be machined the best set of feeding speeds, depth of cut, and turning speeds that would lead to the most efficient use of the lathe (see Figure 1).

The body of technical data amassed by the Taylor-White experiments (and the Wright experiments) represents just one of the types of knowledge described by Vincenti (1990) as being essential in the practice of design. Such bodies of data on materials, their properties, and their operating characteristics are sine qua non in modern engineering design. Comparable bodies of technical data are virtually nonexistent for instructional design purposes. This constitutes a type of finding that would be natural for JAID publication.

Any reasonably competent mill supervisor could apply the wealth of technical data Taylor and White produced. The control that intuitive “experts” had exerted over the quality manufacturing process was transferred to the minimally trained worker employed by a licensee to the Taylor-White data and formulas for applying them. This was licensed in the form of a recipe package in which key process actions and ingredients were encoded and packaged separately so that only authorized users would have access to the full recipe. Ironically, Bethlehem fired Taylor after only 2

Figure 1. A machine-time slide rule with five movable members for calculating optimal feed rates, machining speeds, and cutting for lathe machining of steel using hardened tools. *Journal of the Oughtred Society*, 9(2), 34.
years and four months (because he caused “continuous strife”, which was a personal characteristic eventually noticed by others than Bethlehem), but his work with White placed the hardened tool steel industry on a new kind of “scientific” footing that in a very short time revolutionized the entire industry. Misa (1995, Chapter 5) refers to this epoch of change as the “reform of factories”. This “science” dealt with theories, but they were not grand explanatory theories that tried to make sense of the world: they were theories that later could be used to link the grand theories that emerged later with actual practice. They were technological theories (Gibbons & Rogers, 2009).

In the end, steel production rates for tool steel increased in the range of 200% to 300% due to the Taylor-White research, and the quality of steel products, which had been highly variable before, became much more predictable. Before long, it became apparent that “the new steels demanded factory-level modifications” (Misa, p. 194). This is also a story the instructional design community should be interested in, but that would require another essay.

**Conclusion**

This essay began as a comment on the meaning of the term “applied” as it appears in the title of this journal and the distinctive mission this journal has to perform. The term “applied” in the case of Taylor and White meant much more than just producing a product—getting your hands dirty, embodying someone else’s ideas, creating code and images. Beyond just the interests of the journal, my point is that I believe we have trivialized and overlooked a body of theory that is required to apply high-level instructional and learning theoretical principles during design. On the one hand we are used to talking theory, and on the other we are used to using the keyboard and mouse to turn out a product, but there is a place in the middle that we tend to ignore. It is the middle ground between thinking in theory and making something that actually applies theoretical principles that we are trying to apply in a design.

We appear to assume that by dubbing a design with the name of a prominent instructional theory we actually are applying the theory in a valid way. There is evidence that this is not the case and that the application of theory during design requires a great deal more discernment, rationalization, and bridging theory than we had expected (see, for example, McDonald & Gibbons, 2009). But in technological matters there are no “right” ways: there are only good ways and better ways.

The community of instructional designers should pay more attention to this middle ground of application theory. Its nature is different from scientific theory (Gibbons, 2003). It has been described by Simon (1999), Bruner (1966), and many others (see Glaser, 1976 for an excellent example). It is described in some detail by Vincenti (1990), who points out the multiples categories of theoretical and practical knowledge required by the designer (see especially Chapters 7 and 8). These are required—and applied—whether the designer is aware of using them or not, so it will be of benefit for designers to become aware of them.

Because this is an essay, I have taken the liberty that essays permit of expressing my opinion. However, I have tried to use the example of Taylor and White (and of Wilbur and Orville) to point out that this opinion is not just feverish thinking produced by a deadline.
Is the instructional design community (in all of its habitats and niches) ready for the kind of revolution that would be caused by emphasizing the type of research and theorizing suggested by the example of Taylor and White? Is there currently research that is creating databases that describe the surfaces created by the intersection of instructional variables in the same way the steel-making example described the surface at the intersection of temperatures, timing, and tempering additives? There are several questions involved: Should it be done? How would it be done? What would the research questions look like? What would the research designs look like? What combination of research methods would/could be used? How would the community identify and prioritize the most impactful questions? How would the research be organized? Would it require the formation of collaborative cooperatives for programmatic research rather than individual doctoral studies? Could doctoral studies be made more meaningful in the context of such research programs? And who would fund it?

However these questions are answered, the results of the research should be published in a journal with a title like, The Journal of Applied Instructional Design.

References


According to Pew Research Center, 97% American teens ages 12-17 play some kind of video game (Lenhart, Kahne, Middaugh, Macgill, Evans, & Vitak, 2008). In the last year, the global market for games was $67 billion in annual sales (Gaudiosi, 2012) making this the most profitable form of media being consumed today. In comparison, total movie sales ($10.9 billion) and music sales ($16.5 billion), combined, make up less than half of video gaming revenues (Germain, 2012; Collett-White, 2012). Games are the new media and will continue to grow as a media as production and resources follow consumption.

Games require action on the part of the consumer. To ‘play’ any game, first the user must learn the digital world, challenges, narratives, and semiotic system. In essence, players must be constant learners; learning is intertwined with the actions of the game (Gee, 2003). Game designers seem to have generated compelling environments that encourage game mastery as an outgrowth of play. We suggest that by identifying play activities that facilitate learning and relating them to an established instructional design framework, we can re- invigorate an instructional design staple and perhaps discover insights to exploit game environments for more traditional instructional goals.

For the purpose of this paper, we define play as a voluntary activity that is intrinsically motivating and is largely driven by endogenous goals and choices that can have a make-believe quality (Rieber, 1996). Digital gaming media encourages informal learning of complex game goals through play. Extending lessons garnered from achieving game goals to learning objectives not specifically and solely designed for entertainment is a significant challenge to education.

Csikszentmihalyi and Bennett (1971) state, “Play is action generating action: a unified experience flowing from one moment to the next in contradistinction to our otherwise disjointed everyday experiences” (p. 45). This idea of flow, according to Csikszentmihalyi (2008), is what provides us with the motivation to continue participating in an activity. Games often have these flow features and players can lose track of time
Gagne’s Nine Events of Instruction

1. Gain Attention
2. Inform of Objectives
3. Stimulate Recall
4. Present Stimulus/Lesson
5. Provide Learner Guidance
6. Elicit Performance
7. Provide Feedback
8. Assess Performance
9. Retention and Transfer

Figure 1. Gagne’s Nine Events of Instruction (Gagne, Wager & Briggs, 1992).
Becker (2008) argued that games are a medium that is potentially apt for the implementation of many classic instructional models, yet the models may be embedded in the ongoing play of the game. Further, Gunter, Kenny, and Vick (2006) suggest that in non-educational games, event three (stimulate recall) and event nine (retention and transfer) are often non-existent, but the remaining seven events share numerous commonalities with the principle components traditionally seen in game design.

We propose that a deeper method of artifact analysis will demonstrate that all of Gagne’s events are evident, however these events may be embedded in the game-play throughout the game.

Methods

This study uses artifact analysis methodology to explore the alignment with commercial games with instructional design principles. Artifact analysis is an unobtrusive method to collect information of interest that provides rich and thick descriptions of the artifact of interest (Norum, 2008). We modified Norum’s methods for artifact analysis to use Gagne’s Events of Instruction as the theoretical framework for analysis of a gaming media artifact.

For a compelling study, we sought a gaming media artifact that would be generally accepted as both relevant within the user market, or a ‘successful’ game, and is regarded as a challenging game or one with a complex semiotic system for players to master. After reviewing the top selling 50 games, we purposefully chose Batman: Arkham Asylum due to strong sales, recognition as for its critical acclaim and various nominations and awards including Game of the Year (Gaskill, 2010). We also enjoyed a lower cost to researchers due to its 2009 publish date and subsequent sequels. Batman requires forty to eighty hours of game play to complete the primary objectives of the game; includes multiple play goals (story, action, exploration, and achievement); and requires players to use progressively complex strategies to overcome in-game challenges. Finally, Batman is a commonly known brand and as such can be expected to meet the commonly held expectations of the genre. Participatory fans, like those surrounding the Batman franchise, will often extend play, repeat play, build machinima, explore other media, and/or participate in online social networks outside of this time (Jenkins, 2009) to expand their interactions with the brand.

Our analytic process treated the game Batman as the target artifact for examination of both content analysis and constructed semiotic meaning. Though artifact analysis can vary, and it’s findings are unique to the single artifact, Norum’s (2008) approach to artifact analysis allowed us to gather a thick description of the media with a focus on learning designs included to teach the player the game itself. Norum outlines an iterative process to "infer meaning and make judgements" (p. 24) between researchers by: 1) determining elements of the artifact of interest, 2) applying appropriate questions to the nature of the artifact, 3) identifying themes and patterns, and 4) relating the artifact to the focus of the research.

A digital game is not entirely text, nor is it entirely symbolic so we organized our analysis of the artifact to include text, audio, interface design, and symbolic representations appropriate to the media. Any combination of these delivered media, designed to instruct or guide the player, was coded as an element. For instance an element could be an effort to direct a player to press a particular button. This may be announced with a combination of an arrow pointing at a button, pulsing lightning around the button, text on the button and across the middle of the screen, and a 'ding' sound announcing the need to press the button.

Elements were first experienced by the research team as individual learning elements. The team then met to make judgments to identify all of the parts that made the designed element instructional. We asked questions, modified from Norum (2008), for digital media from the analysis process: What constitutes the designed features of this element? How is it structured? When/how does it appear to the player? Does play affect the appearance of the element (player activated)? What is overtly shown? What is absent? What does this mean to the player? What is the context of this element?

Next we identified themes, patterns, and common symbols used repeatedly by the game designers across elements. We then reviewed each learning element and coded them using Gagne’s Events of Instruction with rich descriptions explaining how they effectively instruct the player via the digital experience. Finally, the team reviewed elements and chose exemplars to share in the findings below that would illustrate instructional design elements used in the game that could be used in other digital media contexts.

Analysis began with the research team playing the game itself for over 160 combined hours (requiring assistance from veteran gamers to finish). During our initial play, we maintained collective journals of observations and specific examples of instructional design embedded in the game itself. After a full play-through of the game, we returned to the first hour of play and collectively replayed it 19 more times. This first hour is the core instructional part of the game. The instructional objectives are to establish player understanding of the controls, core game mechanics, usable tools, play-mode
options, and introduce feedback and trophies for both novice and expert play.

After individual game play, researchers gathered for analysis of the data on a weekly basis over a three-month period. Progressively, all data was operationalized to identify the Events of Instruction; evaluate coherence of framework in digital media; conduct a cultural analysis of the artifact; and interpret application and use of instructional design events. Data points were limited to observations that could be identified and shown in the artifact itself (using a screenshot, award, or completed sequence of play). Final working of the data included identification of clear and compelling points to illustrate digital instructional design. Data was sorted into nine themes that mirror the Events of Instruction.

Findings—Organized According to Gagne’s Principles

Gain Attention

*Batman: Arkham Asylum* makes extensive use of Gagne’s first principle of instruction, which is to gain the attention of the learner. In addition to using sound production to gain immediate attention, *Batman: Arkham Asylum* employs a system of cinematic cutscenes to introduce new tasks or sections of the game. These cutscenes use three dimensional rendering and professional voice acting to create an immersive experience. Cutscenes orient the player to the next task that will be required of them and express both the narrative and challenge the player will face. Movie or cutscenes require minimal skill from the player, unlike actual gameplay, watching a cutscene requires no manipulation of controls, yet often clues to successful play are embedded in the narrative presented.

A movie is used to gain attention and orient the learner at the beginning and at key checkpoints throughout the experience. After some guidance on how to move the avatar (Batman) through the space, the player is left with directives from non-player characters to chase down the Joker and protect Gotham from a full breakout crisis.

This scene progresses in player perspective to effectively ‘zoom in’ on playing *Batman*. First players see the world, then hear the news, then cut to a shot of the Batmobile, then the game places the camera in an over-the-shoulder (typical in action games) perspective that cues the player that they are Batman. Along with cinematic ‘zooming’, the sequence clarifies the objective, the role, and gives clear direction to continue down an elevator shaft to hunt the Joker.

Inform of Objectives

When it comes to describing the goals of the game, *Batman: Arkham Asylum* uses expository story telling interspersed with player controlled progressions. The game alternates between cinematic cut scenes and basic movement training. To advance the introductory sequences, the player must master the controls and skills of Batman the character. Narrative is played out during the cutscenes and the player is given a narrative story in which to frame objectives and new key characters. These help to clarify actions that he or she is expected to learn or problems that he or she expects to solve.

Narrative delivery is seen in one of the early cutscenes with the Joker. After entering the Asylum, the Joker escapes and taunts Batman with the main objective of the game, “I’m getting bored of you, why don’t you come and find me?” Another example of this is also seen in the cutscene where the player is expected to learn how to use the detective mode. The player is then given the goal as objectives (Figure 2). The term objective is used in the sense of a goal to be accomplished and should be contrasted with learning objectives which describe what the learner will be able to do upon the conclusion of instruction.

*Batman* also uses pop up cues (Figure 3) to help guide the player with non-narrative objectives, like learning the controls of the game. Developing facility with game controls and mapping them to gameplay is an implicit learning objective. When a specific combination is needed to pass an obstacle, the game uses a...
visual reminder of the combination on the screen to remind the player of the technique in question. Initially these are in the form of pop up instructions like, “Use ‘W’ to move forward” that prompt the player to master movement controls and later special detective and combination moves that add options to playing the Batman character. In addition, these pop-up cues direct the players attention to the in-game badge system, ‘Riddler trophies’ (exploration rewards), and optional goals the player can choose if they appeal to their play/learning style.

The implicitness of learning objectives is one of the unique methods of implementing instruction through a gaming experience. Gagne’s Events of Instruction implies an explicit introduction of learning objectives to the learner. It is an empirical question to determine whether implicit or explicit learning objectives are superior in terms of achievement and motivation. However, it is clear that game designers often mask their learning objectives by embedding them within gameplay.

**Stimulate Recall**

In order to stimulate the recall of prior knowledge, *Batman: Arkham Asylum* utilizes a reminder system that is similar to the way that the information is initially presented. If the player struggles later in the game, the pop-up reminders (above) return to help the player – requiring programmer attention to tracking performance and having the game recognize when the player requires recall help. This can be seen in the Counter Punch action as depicted in Figure 2. This is also an example of Gropper’s progressions (providing and then fading cue support).

Notice in Figures 3 and 4 that the player is shown in yellow what button to press, but also in ‘lightning bolts’ when to use that button. These two visuals occur together when the player is not using the ‘counter’ to prevent damage to the player and the software determines that the player needs a reminder lesson.

Once again, stimulating recall is accomplished explicitly through cutscenes and implicitly through cues provided to the learner in real-time. The immediacy of cuing is completely contextualized at the micro-level of gameplay.

**Present Stimulus / Lesson**

*Batman: Arkham Asylum* presents material to be learned by the player within the play of the game in a variety of ways. The first is in information that is gained during the cutscenes, as noted above. Along with clever challenges, the player is directly addressed to learn new lessons. This direct approach is used more commonly at the beginning of the game. In addition, *Batman* uses non-player characters, or Batman engaging in self-dialogue, to describe what new action or strategy Batman could utilize to complete a particular goal.
instance, when tracking a bullet shot at Batman, he may say to himself that he should look for clues by using detective mode. This method of presentation is shown in concert with a pop-up showing what button to press for detective mode – or a scanning function the character uses to find clues. Often, the non-player character Oracle describes how the method can be utilized to follow trails that will allow Batman to track certain non-player characters. Oracle is in radio communication with Batman throughout the game, but is used primarily when new lessons are being introduced, and the player can listen in on a directive conversation. Stories have been suggested to provide a uniquely appropriate method for relating content with one’s cognitive structure (Schank, 1995). Batman utilizes a story trope to provide context to the game. Game dialogue is used to inform the learner of stimulus material.

The second presentation type in Batman: Arkham Asylum is a just-in-time style of instruction that shows the keyboard and mouse combinations for a specific action that can be taken by the player as Batman. As noted above, these instructions pop up on the screen as certain movements became possible for the player to perform, as evidenced in Figure 4. The player is expected to use the combinations and to access the skill listed. This allows the player to do what the player was told at the top of the screen. This general presentation style is used in instructing the player to navigate combat and detective sequences, but is not a separate tutorial or instructional design, it is embedded in the play of the actual game.

Figure 4. Pop-up instructional design in Batman (Batman Arkham Asylum, 2011).

Figure 5. Detective mode learner guidance in Batman (Batman Arkham Asylum, 2011).
Provide Learner Guidance

Detective mode, once taught is a key resource for providing learner guidance. At any time in the game, Batman can switch to a lens called detective mode. This transforms the entire view of the world into grey and blue tones, but makes usable objects stand out in a glowing red-orange color. In this mode the player is able to see contextual clues about what they were meant to do next by looking at the different color highlighting on objects. There were also small written reminders on different objects about their abilities as well as side pop-ups. If the player is in regular mode and presented with a grate, they are just given the option of opening it when they come close enough to the grate – without the additional information (Figure 5). Learner cues are always present, but require the learner to activate it with a single click of the button. Again the guidance is not overt, but ever-present and built into the experience of the game.

When a player dies during gameplay, he or she is given timely feedback on where they went wrong. This is depicted in Figure 6. This example shows what when wrong in-game, “You were seen and the hostage was killed,” which reiterates the primary objective of the sequence. The second portion, suggests a strategy to the player, “Approach Zsasz from the rear” that can help the player with a new tactic if they need a new direction. In this particular example, approaching from the rear requires a more subtle, and Batman-like, set of actions.

The difference between this and most forms of instructional feedback is in the delivery method. The instructional sentence was small on the screen, where the feedback (after defeat) is prominent on the screen, provided immediately after an error in play, and accompanied by villain mockery – that is a kind of reward to experience. The game is segmented and a variety of villains appear, based on which ‘chapter’ the player is working on. Each has multiple audio clips so repeated failure is mildly rewarded with new audio and animation. The cost of failure is otherwise very minimal and only delays play a few moments. The player is quickly returned to their most recent save point and is able to try again.

Elicit Performance

Batman: Arkham Asylum makes heavy use of eliciting performance from the players. After each skill is presented, the learner is given a sequence in which they can practice their newly acquired skill several times. Skills also compound throughout the game. These practice opportunities are at an easier level then the general gameplay, yet players can choose to enter a practice mode for combat outside the game. Creating a non-narrative practice portion of the game is slightly different from providing cues within the main game. Players must choose to exit the game to enter the practice sessions with the intent to improve their performance specifically and knowing that it will not progress their in-game progress in any way.

Batman cycles back to core skills and players are expected to use new skills alongside earlier learned skills. Each introduction of a tool or ability builds a new set of possibilities and combinations for the player that exponentially increase performance options and choices for the player. For example the addition of a zip line is in itself a new performance requirement to use, but it incidentally introduces new ways to ‘take down’ opponents, crash through walls, navigate the space faster,
and overcome obstacles that may have previously been blocked in the game.

Increased performances are also encouraged with an award system that recognizes when the player makes use of Batman-like behaviors, combinations, unique solutions to challenges, and/or overcomes especially challenging aspects of the game. For instance, a sneak attack takes much more time than a direct attack, even eliciting patience in the player, but it is more in tune with the Batman character and is recognized with unique animations, awards, challenge directives, and non-player character response audio (in addition to their heart rate increasing if you are inspecting them in detective mode). Expert play is encouraged by rewarding the player with production art, 3D models of all in-game characters, and a collection of audio files that tell backstory--none of which are needed for completion of the game, but are nevertheless delightful additions and collections to complete. Players therefore have a choice on how to proceed, but are rewarded for role-play, exploration, and repeated efforts to master content at an expert level.

Typically improved performance is not the product of failure, but in a highly engaged state, or in activities that the learner is committed to, failure is an acceptable state toward increasing outcomes of performance. Players can learn from failure and the attention put on fail states in the game provides evidence that game designers have accounted for, and likely designed for, multiple failures. For example, boss fights routinely have multiple stages to the fight. Mastery of the first stage may require multiple attempts for a novice player just to see the ‘skills’ of the villain and to develop response strategies. Once mastered however, the villain will change tactics mid-challenge (usually when the player has had a set number of successful ‘hits’ or successful strategies) and win with these new tactics. Part and parcel of Batman is to lose boss fights multiple times in order to see these stages to the fight, master each portion, and ultimately over come not just a single opponent, but multiple, and progressively more difficult, stages to the challenge. Designers invest time to include humorous taunting, tips, quick reload times, and unique ‘defeat’ animations to make each failure mildly rewarding.

Provide Feedback

A variety of positive feedback is given when players progress and overcome challenges within the game. First, by defeating opponents, the player is able to clearly see their improvements and gain a firm grasp on what actions are effective and which are not. The player successfully getting through various sections in the game is a sign of success and improvement in skills and abilities. The narrative of the story is also a form of feedback that advances the player through a compelling and twisting mystery style plot line.

Throughout play, sound effects are used for feedback tools. When the player as Batman strikes or otherwise injures an opponent, the opponent makes a grunting sound that indicates that they have been hit. The same is true of the player as Batman. The sounds in the game are used to let the player know when enemies have hit their avatar.

It should also be noted, that surrounding the game itself, we identified a community of expert gamers that took the time to video capture segments of game-play and post them online for others to review and comment on. The best exemplars of puzzle solutions, strategies, or displays of expert play, were rewarded with a higher ‘hit count’, or number of views, and positive comments from other players. This external online community is an easily overlooked, but core social aspect to gaming media as part of a larger participatory culture (Steinkuehler & Williams, 2006; Jenkins, 2009). Though the production company doesn’t overtly design this space, it actively served to motivate this research team toward expertise and participation.

Finally, as each element of play rewards Batman-like thinking and solutions, we agreed that progression through the game correlates with a ‘fiero’ like realization that you are becoming and thinking more like Batman. Without a clear moment that we could identify, however, this form of internalized positive feedback was consistent and authentic to our research team, but difficult to document in the analysis.

Assess Performance

There are several ways in which performance was assessed during Batman: Arkham Asylum. The first way is through the game’s level of completeness. All progression in the game requires a new level, or use, of skills, strategies, and mastery of the semiotic system. To reinforce a sense of story progression, the player is shown the percentage of the game completed whenever they began playing on their saved game screen. Core story elements are essentially rewarded by progression, however an assessment of expertise is layered in by providing feedback for exceptional play as well.

The achievement system shows both novice completion of essential skills and tasks, but also includes a layer of ‘badges’ that recognizes expert and highly demanding optional challenges. The optional awards thus serve as a gauge of performance that highlights progression and completion rather than deficiencies in performance. Players are cued to potential expertise by being able to see awards (greyed out), what they are for, and they can build a self-assessment of performance and internally generated set of goals. For instance, members of the research team built small mental “to do” lists
when we entered the game space and would briefly leave the space for new goals when challenges were completed in-game.

Another method of assessing and rewarding performance is also available through the experience point system in which the player can unlock certain upgrades after they had gained points through defeating opponents. (Figure 7) New gadgets are uniquely rewarding, and provide completely new options within the game—making them awards and challenges at the same time.

To contrast this, boss battles are challenges for the player in which they are faced with a villain, who is notable within the Batman universe. They are both end-of-chapter challenges and rewarding for Batman fans to encounter. These are performance assessments as well: each villain requires a unique use of skills, gadgets, timing, and control of the character to be defeated. The challenges include overcoming Scarecrow, Poison Ivy, Killer Croc, Zsasz, Harley Quinn, and the Joker—each requiring a completely different set of solutions. During these battles the player has to use their tools to overcome an opponent that is different and much more difficult than the simple lower level non-player characters that they encounter. Player-generated ‘walk-throughs’ can be found online for players that get stuck, but even watching these does not serve to bypass the embedded performance assessments. These battles stand as tests to the player and, once the player finished a boss battle, they are ‘passing’ part of the game.

Retained and Transfer

Batman: Arkham Asylum provides enhanced retention and transfer through copious practice and a spiralizing learning design. Once a skill is learned and the initial practice opportunity has passed, continuous chances for practice are rooted in the game-play. Once a player learns to grapple using gargoyles, there are regularly gargoyles in various locations as an option for the player to use. These gargoyles are integrated into the gameplay and are not discarded once the player has learned how to use them. Later in the game, the player uses the same technique to climb scaffolding in an attempt to rescue Commissioner Gordon.

There are also transfer situations. For instance, while the player might have learned to grapple using gargoyles, they are later expected to apply these abilities to walls and other objects. In addition, skills learned in the first instance of Batman: Arkham Asylum are also key game mechanics in the follow up Batman: Arkham City. Retaining and transferring knowledge from one game to the next provides useful expertise within the game. Simple movement mechanics are also common across all first person adventure games like Assassin’s Creed, Call of Duty, Fallout, or Dragon Age and served as useful references for our research team. These navigational skills are instructed for novice players in Batman, but expert players can transfer their navigational literacy from one game to the next and progress very quickly through beginning levels.

Discussion

Each of Gagne’s Nine Events of Instruction were identifiable within Batman: Arkham Asylum. Batman clearly requires learning to master, and game designers developed an instructional design that artfully and effectively gains the player’s attention, informs, stimulates recall, presents stimulus, provides guidance, elicits performance, provides feedback, assesses performance, and rewards retention and transfer of gaming mastery.

Figure 7. Achievement and award assessment in Batman (Batman Arkham Asylum, 2011).
Using Gagne’s Events of Instruction as a framework for assessing a game we argue that *Batman* is a strong model of an instructional design in addition to being an award winning and top selling gaming media.

Our analysis showed two strengths with the instructional design that we suggest are uniquely amplified by the digital nature of the instructional design and can be universally applied to digital media instruction. Namely *Batman: Arkham Asylum* was exceptional at encouraging trial and error, and embedded, context specific support.

**Trial and Error**

*Batman* engages the player through successive opportunities for practice with particular focus of trial and error. Failure is a design feature easily accommodated and encouraged as part of gameplay. Expectation failure is a memory technique common to games and learning. Schank, Berman & Macpherson (1999) in their Learn By Doing instructional model, suggest that expectation failures like those in *Batman*, are a critical component in memory. In *Batman: Arkham Asylum*, there is little consequence to failure, and the player is encouraged to fail over and over with unique villain comments, animations, and low retry times. Refining and adjusting after each attempt allows a progressive sense of progress despite failing attempts.

Boss fights especially had stages within a single fight that built an expectation of failure when encountering a new challenge. We found that failure is expected, welcomed and encouraged in *Batman*. This has also been identified as a quality across gaming media by Juul (2009) and he suggests that failure as a learning tool is a unique opportunity for designers within digital media spaces. The expectation of, tolerance for, and overcoming of failure is learned and worthy of many professional expertise-building activities.

This failure process, referred to as expectation failure, encourages calculated adjustments that eventually lead the learner to success—which is then indexed in memory to be applied to future challenges. Failure provides a reason for practice. As the learner experiences failure as a common element throughout the game and makes adjustments to their game play, they learn how to be more successful in future game challenges. In fact they can fail right up until they ask for support.

**Player Activated Supports**

The feature referred to as the detective mode, can be toggled on and off at any point during game play, but the player must activate it. Four of the five help examples above require that the player activate the help feature within the game. We consider these in-game features to be embedded in the game by the designers. We find it useful to point out that *Batman* respects the learner by providing help when ‘requested’ by player activation. This form of on-demand help uniquely provides feedback when *it is wanted*, not when it is pushed by the instructional design.

Research shows that learning a skill is facilitated to the extent that instruction *tells* the students how to do it, *shows* them how to do it for diverse situations, and gives them *practice* with immediate feedback, again for diverse situations (Merrill, 1983; Merrill, Reigeluth, & Faust, 1979). This *just-in-time* feedback ensures that help is just a click away and supports Keller’s ARCS model of motivational design (Keller, 1983), by instilling confidence and satisfaction in the player.

As players master one level using the help mode, they are able to generalize or transfer the skill to the full range of situations they will encounter throughout the game (Keller, 1983). We suggest that this learner-activated approach to feedback is part of what attracts players to challenges in games, while distancing learners from test scores and instruction. Specifically, we noticed in our own play that feedback was not welcomed from fellow players when our research team felt they were 1) already seeing venues for new play strategies, 2) wanting to fail in order to see new animations, 3) or were feeling mild frustration with competency. In these instances, feedback was seen as annoying and unwelcomed.

Yet in order to design digital experiences that are both challenging and achievable, it is inevitable that various learners will need some guidance at some point. By placing control of feedback on the learner, and making it an ongoing resource, feedback on-demand was found to be welcomed, relieving of frustration, and highly informative for new approaches. The adage of ‘Only give advice when asked’ held true in this study and we encourage an expanded investigation into this singular phenomena across games, genres, and digital media for better and more game-like instructional design.

An unexplored element of player-activated instruction is the contextual community of practice that players develop without direct guidance from game designers. These game communities have been explored to some extent already (Steinkuehler, 2006) and include walkthroughs, forums, hint guides, and videos that support the learner. These are common for top shelf games, yet the game designers do not necessarily have any part in their creation or maintenance. We consider them to be assumed on-demand supports that permit the designers to create challenges that may not have direct or embedded instructional aids or solutions in-game. However our focus here remains on embedded supports.
Strong Correlation to Principles of Instruction Design

We find that the nine Events of Instruction are each seen multiple times within the game. This is consistent with Gagne’s theory in that the nine events are recursive, non-sequential, and can be applied both at the lesson and the overall curriculum level. However, Gunter et al. (2006) contend that, “It does not appear that an entertainment-based game analog exists for event three (stimulate recall) or event nine (retention and transfer) that keeps the spirit of Gagne’s work,” (p.11). In analyzing Batman through the lens of Gagne's nine Events of Instruction, there is evidence to suggest that event three (stimulate recall) is implemented throughout the entirety of the game in both overt and embedded ways. The reminder system stimulates game-player recall by reminding players of keyboard and mouse combinations through overlays at critical points in the game, however the player needs to display repeated failed attempts in order to activate this help mode. This would mean that successful players would never see events to stimulate recall if recall of skill is not needed and it would be easy to imagine that an expert gamer would never see these stimuli. We propose that the absence of overt and forced stimulants does not imply that they are not part of the instructional design in the digital media, only that they are artfully provided when needed and that the media itself uses data inputs to determine the learners’ need for stimulants.

Finally, event nine, (retention and transfer), is also used extensively throughout Batman: Arkham Asylum. Drill and practice are implemented throughout the game to develop the basic knowledge and skills required to play the game and take the player to a level of automatic and errorless performance. Transfer is also evident as the player learns to apply the skills learned in one part of the game to other parts of the game.

In this artifact analysis, we only look at a single game Batman: Arkham Asylum as an exemplar of successful commercial games. We accept that a small focused study, such as this, study can be criticized by its lack of representativeness, generalizability and restrictive nature of the research design (Yin, 2008). Yet due to multiple replications of single case studies, evidence from multiple cases is often more reliable, results and conclusions derived from this design are more powerful, so that the study in general is more robust (Herriott & Firestone, 1983). Future studies can build this base of understanding and defining of effective instructional design within the emergent media of digital gaming. The failings of a single artifact analysis are also indicative of the need for collecting a larger spectrum of data and thus leveraging the external validity and reliability of research conclusions.

As digital media has become more prevalent, there has been an increase in literature looking at designing digital media instruction. We suggest that through meta-analysis of existing instructional design models, it is possible to find many combinations of instructional tools that address the specific needs of digital media. By examining these combinations, models that have been proven over time to be effective design tools can be used effectively to meet the changing needs of instructional designers working with digital media.

Using artifact analysis we looked at learning in Batman: Arkham Asylum through the lens of Gagne’s Nine Events of Instruction. We find that all nine Events of Instruction are integrated, both overtly and embedded within, the design of the gaming media. Moreover we suggest that these design choices can be adopted and applied in any setting mediated in a digital setting toward improved learner-centered instructional design.

We found that by encouraging failure as a natural learning state, players experience expectation failure without consequence. The just-in-time persistent help created by the detective mode feature in Batman: Arkham Asylum provides contextual information about the game environment. Players are able to control the detective mode with a click of a button to quickly assess their situation within the game.

Ultimately, we find that there are natural parallels between instructional design and video game design. It appears that the game focuses uniquely on applied practice, story telling, and embedded and contextualized support to further gameplay and assist in the generation of “flow”. We encourage the examination of traditional instructional designs in an attempt to use and experiment with these attributes to leverage the attractiveness of gameplay for the learner. Though the two fields appear different at first glance, there is a great potential for both of them to inform and improve each other in the future. We suggest, that in future instructional design that these events are not just additional, but core game events that cultivate mastery of the digital space, problem solving, and trial and error learning.

References


