Dr. Bruce Gooch
Research Goals

1 Problem Statement

The goal of Professor Gooch's research is to develop new algorithms and user interfaces that enhance learning. Dr. Gooch's current research address the divide between *entertaining games* and *educational games*. Here, the term *game* to is used refer to video games, such as those played on a computer or video console, as well as online-multiplayer games and mobile device games. Modern games are sometimes characterized by their capacity to capture a player's attention for hours on end; such games are generally considered to be *entertaining.* In contrast, *educational* games are often described as boring.

The widespread appeal of games among children and adults creates an opportunity for the delivery of educational content. In the United States and Canada, about 60% of the population age 6 and older from all socioeconomic backgrounds and both genders enjoy playing games [2]. Families who own computers spend more time playing interactive computer games, i.e. an average of 1.2 hours per day more, than on any other computer activity in their home [2]. Books, movies, and classes provide didactic content, but personal study using such materials frequently relies on rote memorization. A compelling game may expose players to essential concepts in a more stimulating manner. Gee [16] identifies properties of computer games that engage players in active, critical thinking that informs their decisions in both the virtual and real world. Using an interactive game, players have unlimited opportunities to rehearse new skills and receive personalized feedback on choices made during game-play. Moreover, the social components of interactive game play may elevate the player's motivation. Games may have the potential to augment traditional education in ways that improve learning. Educators often marvel at the time young people spend playing video games. Because players often master complex situations provided in entertaining video games, it suggests that players are learning during the course of such game-play. For example, Halo 3 and Age of Empires may teach many 21st century skills such as adaptability, self-direction, risk-taking, interactive communication, prioritizing, planning, and managing of resources.

The same attentive learners do not generally devote a comparable amount of time to playing educational games. Because the field is still in a nascent stage, results of such work remain anecdotal. Currently, educational games do not enjoy the market penetration of entertaining games: of the top forty video games of 2006, the only educational game present is "Brain Age" [2]. Educational researchers have recently begun experimenting with games as pedagogical tools (i.e. serious games) across multiple domains, including history, business, physics, mathematics, language acquisition, and computer science education.

The long term goals of Dr. Gooch's research are identifying the capacity to learn via game-play, and understanding how to teach a given set of material using games.

2 Summary of Proposed Research

In order to meet the the goals identified in Section 1, Dr. Gooch will conduct research in three areas: assessing and evaluating the learning potential of games, building entertaining educational games, and evaluating learning in game supported contexts.

2.1 Assessing and Evaluating the Learning Potential of Games

There are many possible approaches to consider when assessing and evaluating the learning potential of games. Some of the approaches that Dr. Gooch intends to address include: topic coverage, accuracy review, comparative evaluation of relative efficiency, rigorous measurement of relative efficiency, review of transferability and holistic evaluation of perceived educational utility. It is anticipated that other approaches will present themselves and be adopted as the

research program progresses.

Topic coverage: Piecewise examination and rating of the coverage of games will be undertaken to set collections of topics across individual dimensions. Comprehensive collections of topics will be pulled from existing state and provincial curriculum frameworks and refined into appropriately balanced topic sets through a consensus building process among subject matter experts (SMEs). Results might be presented as survey of topic coverage ratings experienced during typical game play or a typical game cycle and presented individually, by class and across the industry. Periodic review and refinement of topic sets would be planned to support the maintenance of a meaningful assessment tool.

Accuracy review: Expert review of accuracy of game content with respect to topics on various dimensions of interest (e.g., language usage, physics, logic, chance, etc.) will also be explored. Although this approach is somewhat subjective, collections of these ratings and subsequent presentations of distributions of ratings for individual games, classes of games and overall might provide guidance to the game development community as to what is valued and what might be missing.

Comparative evaluation of relative efficiency: By bringing together teams of experienced players and dimension experts (i.e., SMEs or graduate students trained to be such) and asking them to compare pairs of games across a small collection of dimensions, a substantial and useful collection of pairwise comparison data can be collected. This data will be analysed using Item Response Theory (IRT) that can generate quasi-interval indices efficiency for the presented games on the selected dimensions. The resulting estimates and scales can be used by parents to compare the efficiency of games across the selected dimensions of interest.

Rigorous measurement of relative efficiency: The rigorous examination of the relative efficiencies of games with respect to learning on each of several dimensions. This option will be more time and resource consuming requiring substantial pools of willing participants and multiple cycles across multiple games and the construction of formal assessment tools for each dimension studied in this manner. It is anticipated that small subsets of dimensions will be carefully selected to maximize utility using the information generated from the research approaches mentioned above and feedback from parents and other researchers.

Review of transferability: A qualitative and quantitative review of the transferability of concepts and procedures from games to other activities by students and adults will be undertaken. Gamers will be presented with authentic performance assessments that have been linked to activities in games and comparisons will be made between gamers given a) instruction in transferring concepts and procedures, b) tutoring to support transfer and c) no intervention. Mechanisms to support transfer will be evaluated for efficacy.

Holistic evaluation of perceived educational utility: Holistic evaluation of perceived educational utility (PEU) of games will require the development of a useful composite index whereby constituent elements are combined in some weighted fashion to provide adults and children with another tool to support their evaluation of games they or their children are wanting to purchase or play. This index would be defined (and periodically redefined to change to meet changing needs and issues) as useful combination of objective ratings, indices and dimensions (as developed in our research and elsewhere) by a consensus building process within a community of experts.

Dr. Gooch will develop two primary mechanisms to support these evaluation goals. First, he will present a series of "learning with games" workshops for children and youth, with parallel graduate certificate programs for teachers during the summers. Second, he will host an online forum to bring together researchers interested in participating in the evaluation of games.

The prototype workshops will initially be offered at a zero net cost to the participants (i.e., some moderate registration fee, which would be returned to the participant in games and other tangible benefits), but it is anticipated that demand will grow quickly and a fee program may evolve that can support the resources required (i.e., instructors and lab time) to allow the program to continue beyond funding sources.

Dr. Gooch intends to pursue the development of graduate courses and/or graduate certificate programs to support teachers and other interested professionals in developing their understanding of the issues and potentials surrounding

learning with games. Ideally we will be able to construct a graduate certificate program in ”Problem based learning in math and science” which may include graduate courses developed specifically to support this research such as ”PBL in education”, ”Evaluating educational software”, ”Designing educational games”, ”Pedagogical Content Knowledge” and ”Effective questioning techniques”. Several of these courses could be designed to incorporate some elements whereby the graduate students worked with camp students to learn, learn from and evaluate games. It is anticipated that the data generated as a byproduct of these activities could be collected to support the research.

It is further anticipated that some teachers completing such a graduate certificate would choose to continue on in their education and work toward a M.Ed., M.Sc. or Ph.D. In addition to choosing to undertake some aspect of the research program these students would be recruited to plan, support, teach or manage subsequent summer camps.

The online forum process would include participants from previous summer camps, graduate programs and other interested parties. Discussions would be set up to support the review and refinement of domain specific topic sets, and other issues such as accuracy, transferability, etc. Some online evaluation and pairwise comparison processes may be undertaken once a stable base of participants is developed.

2.2 Prototyping and Building Entertaining Educational Games

The knowledge gained from investigating how games can be used as a learning tool will then be applied to create entertaining educational games. Creating entertaining educational games will be explored in two ways: by adding educational scaffolding to existing games and prototyping new games.

2.2.1 Building Educational Scaffolding for Entertaining Games

Numerous books have been written about game design [15, 24, 37], for commercial or recreational games. Books discussing the technical and artistic details of developing serious games exist [4, 26], but none of these address the issue of rapid prototyping of serious games by transforming commercial, recreational games into serious games. Serious games refer to video games that effectively integrate learning objectives with the benefits of gameplay experiences, including experiential learning, immediate feedback, adaptability of level of difficulty and semiotic meanings [4, 16]. One might question the need to re-design commercial recreational games when one can simply design serious games from scratch. The answer lies in the need to increase accessibility to those who may lack resources and technical ability to develop high quality 3D games. Typically game design requires a team of experienced software developers, modelers, animators, graphics artists, story tellers among others who collaboratively design a game over the period of two to three years. Additionally, commercial games have emerged from the design process with the proven ability to attract players and repeatedly entertain them with fun, challenging experiences that help establish a fan base of players. This broadens the impact of serious games as an educational tool for multiple domains, instead of relying on game development companies to design a game for a specific educational purpose.

Creating mods and plug-ins for currently available games allows us to use the proven ability to attract players and repeatedly entertain them with fun, challenging experiences that help established a fan base of players that comes with a commercially developed game. This broadens the impact of video games as an educational tool for multiple domains rather relying on game development companies to design a game for a specific educational purpose. Dr. Gooch currently has access to and the ability to build educational scaffolding for Microsoft XNA, Microsoft Flight Simulator X, Sony Online Entertainment’s EverQuest II, Half-Life Engine by Valve. He will use this knowledge and technology base to build educational scaffolding into entertaining games for learning domains that we have identified using the results of the research proposed in the previous section. He will then evaluate the effect of these new serious games using the results of the research detailed in the following section.

Dr. Gooch has explored this direction in the past with successful results that we intend to build upon for this proposal. In particular, Dr. Gooch and colleagues [34, 32], inspired by John Nordlinger of Microsoft Research, have created a working prototype in the domain of language learning by implementing an educational plug-in for Sony Online Entertainment’s EverQuest II to support the development of mainstream literacy and second language acquisition (SLA)

as a result of game play. This work has two audiences, teenagers and adult learners over the age of 30. The learning scaffolding is currently being implemented for Spanish and Korean. Dr. Gooch and colleagues have explored the use of game modding in several contexts. The term *modding* refers to the practice of modifying game engines, or using game creation tools, to create new game senerios inside existing games. In particular, they have explored the use of game engines, including Unreal Tournament, Warcraft III, and Wildtangent in prompting knowledge and skills related to computer science (e.g., 3D mathematics, networking, artificial intelligence, and software engineering). In addition, they used game modding to engage high school female students in programming. They ran a high school gaming and girls five-day workshop for 2 and half years. During the workshops they collected qualitative and quantitative data to evaluate the use of modding as a method of learning introductory to programming skills, as well as to gauge the impact of using modding on the self efficacy and attitude women have towards programming. Results suggest that the workshops have been successful in attracting high school girls to computer science, and also at teaching them introductory programming concepts, such as variables, loops, etc. as well as complex constructs such as parallel programming. In addition, the girls participating in the workshop showed increased self efficacy regarding computing and attitude towards IT.

2.2.2 Prototyping Educational Games

Not all learning tasks will map to currently commercially successful games. In addition, game companies may not be interested in spending the large amounts required to build a new game just to meet our needs. With a common development cycle of 2-3 years, teams of hundreds of artists and programmers, 10 million dollar budgets, and risk-adverse management make implementing this in a new educational game impractical. Motivated by Dr. John Buchanan and colleagues' [1] approach for rapid prototyping of new game ideas via "Game Sketching", we propose to create a prototyping environment for entertaining educational games. Using game sketching to create new games allows researchers to explore tutors/teachers as characters in a game or automating their presence via non-player characters.

Games are tools frequently used by teachers to foster student engagement in the classroom. Typically they are used to consolidate learning in a particular domain, but they are also used to promote learning of new concepts. A good educational game should be engaging, have some challenge associated with it, address desired learning goals, but also have some element of uncertainty (hidden factors or chance) to moderate the impact of ability level and thus maintain student interest and engagement.

Technology-based games can be particularly appealing to students as they relate to a form of entertainment that is part of the popular culture of the students life outside the classroom. Teachers, tutors, and educational evaluators are part of the cast controlling both the selection and play of games in educational settings (e.g. classrooms, summer camps, etc.) They not only determine which games are used, but also the mode of usage of the game and the level of external support given to the students during game play. Thus, it is important that individuals in each role gain experience and expertise in evaluating the utility and educational potential of technology-based games and understanding the nature, issues and elements associated with of creation of such games.

We propose to involve teachers, tutors, and educational evaluators as a core component of our centre. They will be both learners and research associates in our assessment of the educational potential and efficacy of technology-based games. We will involve teachers through workshops and graduate programs. They will be encouraged to engage their students in a game sketching process where they examine problems and the associated concepts and procedures that might be learned and demonstrated if that type of problem were to be presented in a gaming environment. Big buddies (older students) might work as tutors with younger students in the development and presentation of prototype game sketches. Additionally, teachers and tutors will evaluate how the games represent and communicate problems, make connections, and provide scaffolding to players (tutees/students), how effectively the game context covers concepts, and how effective game is at supporting new players to master concepts.

Once the learning requirements have been identified, we can create a game specification sketch applicable to a specific domain that outlines five basic criteria [36] 1. the concept or theme of the game, 2. potential learning opportunities present in the game, 3. the appearance of game plug-in using mockups of sample screens, 4. game controls including mouse, keyboard and menu controls, and 5. system behavior of case scenarios that explain how the user will interact

with the game. The characters in the game are not scripted, rather puppeteers are used to control the characters. Once the sketch is implemented the behavior of the characters can be rapidly altered and recorded as reference for the development stage of the game. This approach provides for a rapid development and exploration of game ideas.

Dr. Gooch proposes to extend this line of research in three directions. First, by adding teachers, tutors and educational evaluators to the cast controlling the prototyping game environment. Second, by extending Dr. John Buchanan's game script idea to include educational tasks and classic narrative forms. Third, by leveraging the discoveries of the teachers, tutors and educational evaluators from the first line of research for the creation of an new generation of educational non-player characters.

2.2.3 Support Characters in gaming

There are several research project that explored the use of coaching or support characters in virtual simulations [29, 22, 21]. These simulations embed the player in a 3D environment that simulate a different culture, such as Iraqi village. The player, who is projected as an American soldier, is confronted with a different culture and is required to gather information to complete the mission. The objective of the simulations vary from one to another; Johnson et al.'s simulation for example attempts to teach the player cultural rules and Arabic language, while Core et al.'s simulation attempts to teach the player about negotiation skills and leadership within a foreign culture. Johnson et al.'s simulation includes artificial intelligent non-player characters that act as support characters that coach the player through a cultural situation or mission. Core et al.'s simulation includes an artificial intelligence mechanism for automatic reflection after each mission allowing the learner to self reflect. These techniques are also valuable if one is to use game playing as a method for learning. Dr. Gooch has experience in the area of believable character and user modeling to enable exploration of building support characters, coaches, and reflection mechanisms based on explainable artificial intelligence techniques. Dr. Gooch will augment his game sketch implementation with such systems.

2.2.4 Gaming and Narrative

Understanding Narrative in the Gamming. Narrative refers to the structure or sequencing of events in a story. Theorists who study narrative consider it the organizing principle around which all human communication is formed. We communicate with one another in the form of story. In order to communicate effectively, we must be able to both create our own stories and interpret those created by others. In the humanities, the study of narrative has focused on three areas: the identification of common narrative elements within and across genres, the classification of these elements according to their function within the narrative and, most recently, the study of how these elements can be manipulated by the user in computer-based interactive fiction and games.

Application to Gaming: Computer-based interactive narrative. Narrative theory has already been widely applied in the area of computer-based interactive fiction. Creating interactive narratives poses specific challenges to designers and story tellers because each narrative block must be both internally coherent and able to be combined logically with other blocks regardless of sequence. Theorists such as George Landow have used the language of narrative theory to describe why interactive texts succeed or fail (Landow, "Is this hypertext any good? Evaluating quality in hypermedia"). In order to maintain user engagement, interactive fictions must conform to the principles of effective narrative. Similarly, interactive games must also be based on well-structured narrative. Effective narrative is almost invisible to the game player. When narrative is poorly-constructed, however, it can overshadow all other elements of the game.

Goals. An important first step in the effective use of game sketching to create prototypes is understanding how narrative works. The goal, therefore, of this aspect of the larger project is to communicate the principles of narrative theory to game designers and story tellers. Dr. Gooch proposes to draw upon the existing body of narrative theory to create a resource for game designers and story tellers that will highlight elements common to most narratives and classify these elements according to their function within the narrative. Understanding narrative theory will help designers and story tellers create compelling and believable narratives that will engage the user's imagination and increase his or her involvement with the game. This resource will also help designers and story tellers effectively structure narrative

blocks within a game in a way that will allow users to generate their own story lines by manipulating narrative blocks.

2.3 Evaluating Learning in Game Supported Contexts

We will also explore self-regulated learning as a theoretical frame for empirically examining ”learning” in the context of serious games. Successful learners are often described as self-regulating their learning. These learners are planful, take time to check how they are doing, and deliberately change directions or strategies when learning does not go as planned. Self-regulated learners are: (a) intentional in choosing targets or goals and making plans for learning, (b) strategic in adopting and adapting a range of tools and strategies to improve learning, (c) reflective in monitoring progress and intervening when things are not going as planned, and (d) persistent in the face of challenges [19, 23, 53, 40, 48, 47, 49, 54]. These learners take charge of learning by monitoring, evaluating, and regulating task perceptions, goals, plans, and strategy enactment [49]. To succeed in both solo and collaborative tasks, students need to develop skills and strategies in three arenas: self-regulating, co-regulating, and sharing in the regulation of learning. To date, few empirical studies have considered these forms of regulation in relation to one another or in the context of complex tasks that unfold over time.

Self-regulated learning provides a promising theoretical frame for empirically examining ”learning” in the context of serious games because it considers changes in motivational state (confidence and attitude), cognitive state (factual, conceptual, and procedural knowledge and skills), strategy use, and metacognitive knowledge about how and why some strategies work and others do not. Similarly serious game playing provides a promising context for researching the development of self-regulated learning as it unfolds over time. Dr. Gooch Proposes that successful game playing requires players to develop self-regulatory knowledge, skills, strategies and attitudes that are essential for all successful learning. In order to successfully attune performance in these games, students must develop some awareness of not only their outcome performance, but also of the skills and strategies that led them to those outcomes.

Building on research tools, theoretical platforms, and analytic methods Dr. Gooch will: (a) examine changes in self-regulated learning skills, strategies and beliefs in solo and multiplayer games, (b) refine measures of self-regulated learning that are sensitive to change over time in the context of these games, and (c) rigorously evaluate pedagogical tools and innovative technologies for supporting and researching learning and self-regulation in the context of games.

2.3.1 Methodology

Dr. Gooch will target 4 objectives for evaluating learning in game supported contexts include: (1) developing and testing measures of self-regulation, co-regulation, and socially shared regulation of learning, (2) extending and applying analytical tools and methods for examining the regulation of learning, (3) conducting applied research studies of self-regulation (motivation, cognition, strategic behavior, and metacognitive knowledge) as it unfolds in game playing contexts, and (4) empirically examining the effectiveness of technologies and add-ons to games that support students to improve self-regulated learning by reviewing and reflecting on their own game play strategies.

Goal 1: Develop and adapt current measures of self-regulated learning that are suitable for empirically examining learning in the context of solo and multi-player games. Dr. Gooch will develop and evaluate software solutions for the collection and analysis of user data. Dr. Gooch is experienced with both qualitative and quantitative evaluation of software for individual users and groups of users. Measures will target six facets of regulatory activity: strategy use, strategy knowledge, metacognitive monitoring, metacognitive knowledge, regulation of motivational state and efficacy. Note that conceptual knowledge or domain knowledge are not central to this portion of the research because they will be examined more extensively by team of collaborators. However, Dr. Gooch does expect to connect these findings across these two aspects of the project by examining the degree to which evidence of self-regulatory skills and strategies predicts performance in domain specific knowledge transfer tasks. Measures will draw across three data sources: (a) log file traces of regulatory strategy use in the context of solo and multi-player games, (b) traces recorded in chat log and game play discussions, and (c) dynamic self-report and reflection instruments such as game play and strategy notes embedded within the games, and more conventional questionnaire and interview instruments.

Evidence of strategy use will constitute the use of tools, scaffolds and social supports for regulating and improving game play. We expect to see a transition from borrowing strategies to developing, applying and co-constructing strategies with others in more experienced players. Evidence of strategy knowledge will include explanations of how, why, and when to use strategies provided in strategy or game play books as well as strategies described during post game interviews. Dr. Gooch expects to see more comprehensive strategies develop with more sophisticated understandings of how, why and when they work in more experienced players. Evidence of metacognitive knowledge and monitoring will comprise checking on performance or strategy use by consulting progress visualization tools or engaging in collective monitoring dialogue with peers, or game playing mentors. Dr. Gooch expects to see more accurate self-assessments and more strategic monitoring activities as students develop expertise. Evidence of motivation and confidence will be draw upon conventional self-report measures adapted for these game playing contexts.

Goal 2: Extend and apply analytical tools and techniques for researching the regulation of learning in gaming contexts. Drawing on past research on logfile analysis, Dr. Gooch will enhance gaming environments with the capacity to collect, analyze and interpret game playing actions. Specifically he will examine: (a) frequency of activities, and (b) sequences and patterns of activities. In addition to drawing on this data to understand the development of self-regulated learning, he will also examine the effectiveness of providing progress visualizations for game players as a means for evaluating, regulating and improving their knowledge, skills and strategies. This goal requires significant collaboration between computers sciences and educational psychologists because sophisticated methods for tracing and analyzing learning are in their infancy.

Goal 3: This goal runs somewhat concurrently with goals 1 and 2, which serve as the backdrop for larger scale applied research studies of the regulation of learning in serious games contexts. Dr. Gooch will examine task performance and six main facets of regulatory activity: strategy use, strategy knowledge, metacognitive monitoring, metacognition knowledge, regulation of motivational state, and efficacy under two different experimental conditions (1) with access to tools for reflection upon and monitoring strategy use, and (2) without access to those tools.

3 Expected outcomes

- A thorough understanding of how users across age groups and genders interact with game technology.
- User models that contribute to both the design and evaluation of serious games.
- Build educational scaffolding for entertaining games via Microsoft XNA games, Microsoft Flight Simulator X, Sony Online Entertainment's EverQuest II, Half-Life Engine by Valve, in order to produce entertaining educational games for specific learning domains.
- Build tools that enable rapid prototyping, testing, and evaluation of entertaining educational games for learning domains that can not be created with simple educational scaffolding on available entertaining games.
- Develop domain constraints, learning objectives, and learning models that will inform the design process of interactive digital media that effectively support learning.
- Adapted measures of strategy use, strategy knowledge, metacognitive knowledge and monitoring, motivation and confidence for serious game playing contexts.
- State-of-the-art tools for collecting, analyzing, and visualizing strategy use in the context of serious game playing
- Increased understandings of the development of regulatory strategies and skills and their effectiveness for: (a) enhancing game playing performance, and (b) predicting the conceptual and domain knowledge accrued during game playing.
- Certificate programs for teachers including "Problem based learning in math and science", with graduate level courses such as: "PBL in education", "Evaluating educational software", "Designing educational games", "Pedagogical Content Knowledge" and "Effective questioning techniques".
- Make the area of narrative theory and entertaining educational games more well known to other researchers and game develpers.

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