New Tools, New Tricks? Evaluating Games and Simulations from Multiple Perspectives

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Abstract
This paper focuses on new tools related to the formative and summative evaluation of online simulations and games for learning, in the context of the Canadian "Simulations and Advanced Gaming Environments (SAGE) for Learning network and its research. The SAGE project is a $3 million, bilingual initiative in which over 30 Canadian university-based researchers from 14 institutions are collaborating with partner representatives to better understand how SAGEs can support learning, particularly through application of current learning theories. In addition to traditional learning assessment methodologies, SAGE is applying a number of new tools and techniques to game and simulation evaluation; this paper focuses on (a) systematic reviews of the literature, as a means of determining the variables related to positive learning outcomes; (b) transcript analysis, as a means of determining types of thinking taking place in problem-based learning simulation sessions; and (c) the Virtual Usability Lab (VULab), a prototype tool for remotely and automatically capturing process and player response data without researcher intervention. We describe these tools and examples of their application as a starting point for discussion and further work on game and simulation evaluation.

Introduction
Games and simulations are widely regarded in the literature as potentially exciting and powerful learning tools (e.g., see Prensky, 2006; Gee, 2003; Kirriemuir & McFarlane, 2004; ELSPA, 2006). However, evaluating their usability and learning impacts poses significant methodological and logistical challenges. This paper focuses on new tools and research questions related to the formative and summative evaluation of online simulations and games for learning, in the context of the Canadian "Simulations and Advanced Gaming Environments (SAGE) for Learning network and its research, with the goal of stimulating discussion on new evaluation techniques and opportunities.

The SAGE project

The *Simulation and Advanced Gaming Environments (SAGE) for Learning* project is a $3 million, bilingual, Pan-Canadian Collaborative Research Initiative funded primarily by Canada's Social Sciences and Humanities Research Council (SSHRC) with additional funding from partners and from Canada's CANARIE Inc. Advanced Applications Program. More than 30 Canadian university-based researchers from 14 institutions, working in education, cognitive psychology, computer science, educational technology, new digital media, and research/ evaluation methodologies, are collaborating with Canadian and international partner representatives to better understand how SAGEs can support learning, particularly in their embodiment of current learning theories.

A key *SAGE for Learning* partner is Société d'apprentissage à vie (SAVIE) Inc. (www.savie.qc.ca), a research and development centre at Télé-université in Quebec City. SAVIE is directed by Dr. Louise Sauvé (SAGE network Co-Leader) and has been active for over twelve years in research and development projects related to core competencies and creating web-based simulations and games. SAVIE is developer and host for the *Carrefour virtual de jeux* and *Educational Games Central* networks for the application of games to learning (http://www.savie.qc.ca/CarrefourJeux/fr/accueil.htm and http://egc.savie.ca).

The *SAGE for Learning project* responds to four trends in Canadian society and learning: (1) the shift in our culture's entertainment toward games and virtual environments; (2) the rapid emergence of simulations and games as popular education and training tools; (3) our growing understanding that learning is most effective when learners collaborate and practice in context; and (4) ever-expanding technologies for developing appealing, immersive, and engaging simulations and games. The project's research objectives are to:

- build and validate a *common multidimensional taxonomy and conceptual framework* to guide SAGE research;
- describe the *types and characteristics of learning* that take place through the use of SAGEs;
- identify, observe, document and model *key cognitive and social processes* that develop, promote or hinder learning in SAGEs;
- study the capacity of SAGEs to *support learning as described by key learning theories* through adaptation and creation of simulations and games for specific learner groups and tasks;
- develop and implement *research methodologies and tools* appropriate for describing and assessing SAGE learning processes and outcomes;
- develop and test *methods for specifying SAGEs as learning objects* for standards-based repositories;
- demonstrate the *application of knowledge* resulting from our research on SAGE impacts in the development, implementation, and testing of prototype SAGEs in the fields of health promotion, health care, and health education; and
- pilot the *implementation* of SAGEs in authentic contexts, e.g. schools, businesses, and community settings.

Research on SAGEs needs to explore many aspects of their objectives, design, embedded models, learner characteristics, media and technology characteristics, learning processes, and learning outcomes, most often in the context of a specific learning application (see, for example, Garris et al. (2002)'s model of game-based learning). To fully understand and improve learning with SAGEs, we need to identify important variables at all stages of the framework and to investigate their relationships, particularly those that lead to improved learning outcomes and positive impacts. Key to doing this are rigorous evaluation methodologies that test evolving learning strategies and new, more complex learning environments (Kneebone, 2003; Wideman et al., 2007). Extensive research is

needed to develop theory-based, rigorous evaluation tools and methodologies that are appropriate to these new learning environments.

To begin to answer these questions, *SAGE for Learning* research is being conducted in *descriptive, developmental* and *evaluation* phases across its four-year mandate. Individual projects are grouped into three Application domains (*Games*, *Simulations*, and *Simulation Games;* see definitions below*)*; and three Foundation domains (*Conceptual Foundations*, *Methodologies and Tools*, and *Technologies)*. Research in the foundation domains supports and integrates research in the application domains, as illustrated in Figure 1 below.

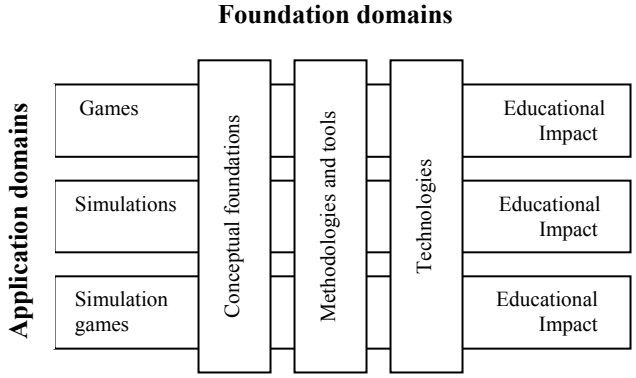

Figure 1: *SAGE for Learning* Research Domains

Projects within these domains are addressing a variety of specific health and medical education applications and foundational issues.

- Projects in the *Games* domain focus on developing and testing "frame games" in Educational Games Central to identify and document game characteristics that help or hinder learning, and to analyze the connections between important game variables and health-related learning impact. Target learners are teenagers, teacher educators, and trainee teachers (Kaszap et al., 2005; Sauvé et al., 2006).

- In the *Simulations* domain, the *Collaborative, Online, Multimedia, Problem-based Simulations (COMPS)* is exploring the potential of COMPS to support problem-based learning (PBL) for medical student education and for continuing medical education for health professionals. They are designing, developing and testing a set of full scale, media-rich, narrative-based simulations in which learners can role-play medical professionals and access realistic resources to guide their diagnoses and treatments (Kaufman & Schell, 2007; Schell & Kaufman, 2007a). The *HealthSimNet* Project is exploring how to create and apply visualization and simulation tools based in activity theory to facilitate learning based on models of complex sets of interactions among interprofessional teams (Dobson et al., 2004; in press).

- *Simulation games* researchers are working to (a) identify factors in game design that motivate children and to build and test generic game shells that can incorporate content from physicians, health educators, or parents, resulting in games that are tailored to the needs of individual children or groups dealing with different diseases (Watters et al., 2006); and (b) exploring questions of education game design, gender and gaming, content development, and narrative frame through the design, development, and testing of the Contagion! internet-based educational simulation game (de Castell & Jenson, 2006; Grozav et al., 2005) to encourage affective, somatic, and procedural dimensions of habitual self-care for health promotion.

- *Conceptual foundations* research is seeking answers to a number of questions, including understanding the characteristics which let us distinguish games, simulation games, and simulations; the cognitive, affective, and motivational aspects of games, simulations, and simulation games; and aspects of a multidimensional framework to guide future research on games and simulations for learning. Based on a major database search, the researchers completed a detailed grid-based analysis of over 450 recent papers on educational games and simulations, focusing on terminology and learning impact (Sauvé et al., in press). They have completed several major literature review papers and a searchable database for SAGE members.

- *Methodologies and tools* research is focusing on (a) measurement and evaluation of activities, interactions, and choices that take place while learners use simulations and games online. One group in this domain has designed and developed the Virtual Usability Lab (VULab - www.vulab.ca) (Owston et al., 2005; Wideman et al., 2007). Another is working on a methodology, based on the detection of users' eye movements in learning situations in 2D and 3D environments, to allow researchers to better understand learning within SAGE environments (Albert et al., 2005).

- The SAGE *Technology* domain houses *ENJEUX-S,* a CANARIE-funded project that has developed an advanced multimedia, on-line, multi-player game and simulation environment (http://www.savie.qc.ca/enjeux/). The web environment (Figure 3) integrates multimedia components (video, voice) with 2D/ 3D games and simulations, allowing for instantaneous and simultaneous interaction so that users in any location can play and collaborate (Sauvé et al., 2005c).

Evaluating games and simulations for learning

Evaluating the learning impact of games and simulations poses many methodological challenges. While many case studies have been reported in the literature, they tend to use small sample sizes and to rely on self-reported perceptions of learning effectiveness rather than attempting to collect and analyze objective data. For example, Wideman et al.(2007) note that given their difficult logistics, few randomized controlled trials are used; little research has been done to document connections between specific game/ simulation characteristics or implementation conditions to learning outcomes; and definitions of "game" and "simulation" vary across researchers, making it difficult to compare or generalize results.

Since both maximizing learning effectiveness and identifying learning impacts are core goals of SAGE research, evaluation questions and methodologies are taking a central role in all of its research projects and, indeed, are the motivation for a separate "Methodologies and Tools" domain. Varying approaches and tools are being used, with an emphasis on starting with clear definitions, assessing usability, providing feedback to learners and developers, and assessing specific learning outcomes based on objective data collection and analysis together with self-reported results. These approaches include:

1. Systematic reviews of the literature, as a means of clarifying terminology and determining the factors related to positive learning outcomes (Sauvé et al., 2007);

2. Transcript analysis, used in the COMPS project to assess the impact of problem-based simulations on critical thinking skills (Schell & Kaufman, 2007);

3. The Virtual Usability Lab (VULab), a tool for conducting research on advanced educational gaming environments by remotely and automatically capturing process and player response data without researcher intervention (Wideman et al., 2007);

4. An activity-theory based graphical reflection tool (Dobson et al., in press);

5. Eye-tracking and psychophysiological measures to better understand the user's game and simulation play experience (Albert et al., 2005);

6. Analysis of extensive game performance data collected by the *Educational Games Central/ Carrefour virtuel des jeux* frame game system in order to determine the cognitive learning impacts (Sauvé et al., 2006); and

7. Traditional social science evaluation methods, including pre- and post-tests of knowledge, behaviour and attitudes; interviews; focus groups; and observation.

The remainder of this paper will focus on the first three of these tools.

Systematic reviews of the literature

In order to establish a theoretical basis and guidelines for an effective analysis of the learning impacts of games and simulations, SAGE researchers are conducting an extensive review of the literature on educational games and simulations. The first goal of this review has been to clarify terminology by identifying the essential attributes of games, simulations, and simulation games as articulated in the literature:

> Based on this analysis, we define a game as a fictitious, whimsical or artificial situation in which players are put in a position of conflict. At times, players square off against one another; at other times, they are together and are pitted against other forces. Games are governed by rules which structure their actions in view of an objective or a purpose which is to win, to be victorious or to overcome an obstacle. They are integrated into an educational context when the learning objectives are associated formally to the content and the game enhances learning in the cognitive, affective and/or psychomotor domains.
>
> We define a simulation as a simplified, dynamic and accurate model of reality that is a system used in a learning context. Through its model, judged by its fidelity and its similarity to the reality it represents, a simulation is distinguished from a game, which makes absolutely no reference to reality. These attributes of a simulation are essential to its use in addressing educational objectives and to allowing learners to study complex and real phenomena, which is not the case with a game (Sauvé et al., 2007a, p. 2).

A simulation game occupies the middle ground, incorporating the essential attributes of a game within a simulation model context.

These distinctions have led us to segment the literature into three broad categories and to further analyze reported learning impacts within each category. Our systematic analysis of the learning impacts of games and simulations (Sauvé et al., 2007b; in press), based on 524 studies since 1998, confirms the absence of consensus on the terminology used (the concept of game is loosely defined) and on the essential attributes of games differs across studies, weakness of the theoretical framework of the studies, deficient methodology (lack of operational definitions of the studies variables), lack of connection between the theory and the application in the research environments (often, the activity being studied is not a game), results too often different and impossible to compare. More specifically, the studies use few, or no, analysis indicators to measure the

effectiveness of games and simulations, especially when it comes to knowledge structuring, information integration and cooperation and communication skills. However, there are notable efforts for problem solving and human relations skills.

Faced with these findings, we have done a first review of the educational literature in order to identify some indicators for these impacts. We are presently working on their operationalization inside an analytical grid, which will be the first methodological milestone for demonstrating the factors related to the effectiveness of games and simulations in an educational context.

Transcript analysis

Content analysis of group discussion transcripts is an established evaluation method for research in computer-mediated communication (CMC) and computer-supported collaborative work (CSCW); this approach readily extends to online discourse during the conduct of collaborative game or simulation activities. It involves defining units of communication that mark the attributes or outcomes being measured, coding transcripts to identify the units, and conducting a statistical analysis of the coding data.

Transcript analysis, based on the coding scheme used by Kamin et al. (2003), was used to evaluate the COMPS prototype Problem-Based Learning module with respect to its promotion of critical thinking in learners. This pilot study, described in more detail in another paper at this conference (Schell & Kaufman, 2007b), showed promise as a way of developing evidence of learning impacts for collaborative games and simulations.

Virtual Usability Laboratory

The VULab (Wideman et al., 2007) is a web-based tool developed to address methodological limitations of game evaluation and particularly to allow researchers to record and analyze complex processes, interactions, and outcomes that result from gameplay. Originally designed as a tool to test the usability of healthcare information systems, VULab has been extended to allow remote, automated capture of detailed process data with unobtrusive techniques that do not interrupt players or require extra equipment or researcher presence, and a "virtual videotape" is created of the gameplay, along with optional recordings of player verbalizations and student-teacher interactions. It can also record logs of specific player activities and player responses to pop-up questionnaires inserted at any point during gameplay. Data is stored in a relational database for analysis.

In a pilot test of the usability of a specific game on the Educational Games Central frame-game web site (URL), analysis of VULab data identified several technical and usability issues with the game, but also documented student enjoyment of their play experience. It is now poised for further development and large-scale use as part of the newly-funded FLUID project (http://fluidproject.org/). We look forward to expanding our game and simulation research capacity through new research questions and methodologies using the VULab.

Conclusion and future directions

This paper has identified seven classes of methodologies and tools and has described three of these that are intended to measure the process and; or outcomes of educational games and simulations. There is a rich palette of choices that have been shown in other contexts to be helpful in uncovering the factors related to learning, both in the cognitive and affective domains. Traditional methods such as surveys, tests, interviews, and others have been employed for many years, and have been our core measurement tools for educational research. In this paper we have argued that other methods, such as systemic literature reviews, transcript analysis, and technology-based methods (e.g. VULab) can add significantly to our understanding of the domain of games and simulations. Further research will focus on more in depth applications of these methods.

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