Simulations and Games for Learning: A Canadian Research Agenda

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ABSTRACT

This paper provides an overview of the research agenda for the "Simulation and Advanced Gaming Environments (SAGEs) for Learning" INE Collaborative Research Initiative. The purpose of this project is to explore the potential of games, simulations and simulation games to support learning in light of new technologies, new media and our knowledge of cognition and learning processes.

Introduction

This paper provides an overview of the research agenda for the "Simulation and Advanced Gaming Environments (SAGEs) for Learning" INE Collaborative Research Initiative. The purpose of this project is to explore the potential of games, simulations and simulation games to support learning in light of new technologies, new media and our knowledge of cognition and learning processes.

The research has the following objectives:

- To construct and validate a *common multidimensional taxonomy and conceptual framework* to guide SAGE research;
- To describe the *types and characteristics of learning* that take place through the use of SAGEs;
- To identify, observe, document and model *key cognitive and social processes* that develop, promote or hinder learning in SAGEs;
- To 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;
- To develop and implement *research methodologies and tools* appropriate for describing and assessing SAGE learning processes and outcomes;
- To 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
- To pilot the *implementation* of SAGEs in authentic contexts, e.g. schools, businesses, community settings.

The major outcomes of this initiative will be advances in and widespread dissemination of Canada's knowledge and best practices for SAGE-based learning support, specifically including guidelines and methods for (1) SAGE design and testing within the context of learning situations, goals, and models; (2) adaptation of educational methods to include

SAGEs; (3) selection of effective, complementary SAGEs and instructional methods, and (4) training of Highly Qualified People in SAGE research.

Our work focuses Canadian resources and expertise on the above objectives, positions Canadian researchers as active participants in this growing field, and establish mutually useful relationships among researchers and major simulation and game developers. Our project is supported by a national network of academic and industry experts, and international partnerships will be established to ensure that Canada benefits from and contributes to leading work internationally. Knowledge translation between Anglophone and Francophone participants is an added benefit; in particular, this makes accessible to Anglophone researchers extensive work on SAGEs and health education done by Francophone colleagues (e.g. Kaszap et al., 2002; Renaud & Sauvé, 1990; Sauvé, 2002; Sauvé et al., 2002a,b). Finally, we are leveraging this project to obtain additional funding to build a strong, ongoing base of Canadian SAGE experts who can more comprehensively address this large and complex field.

Background

Games, simulations, and hybrids of the two (simulation games) encompass a wide range of activities that can support play, entertainment and learning (Stolovitch, 2002; Streufert et al., 2001). Today's versions are based on earlier tools that have been widely used since the 1960s for education, training and performance assessment in military, aeronautical, business, health education, public health promotion and other disciplines (Faria, 2001; Issenberg et al., 2001; Lane et al., 2001; Lederman et al., 2001; Nehring et al., 2001; Powell, 2001; Ross et al., 2001; Starkey & Blake, 2001). At primary and secondary school levels, they have been applied in the teaching of many disciplines including mathematics, environmental science and health; for examples, see Boyle et al. (1994) and Johansson & Kuller (2002). Health-related learning applications have mushroomed in recent years, fed by advances in technology and medical knowledge (Lehmann, 1998; Tatti & Lehmann, 2001).

The phrase "simulations and advanced gaming environments" (SAGEs) reflects the transformation that is taking place as games and simulations incorporate new technologies. SAGEs can, or will soon be able to, employ sophisticated, detailed virtual reality representations of physical settings (for examples, see Barnes (2000) or many of today's commercial video games); wireless handheld devices or cell phones that allow instant communication and feedback (for example, see Danesh et al., (2001); game boxes to bring games to the family living room; Internet-based multiplayer games; head-mounted displays; or 3D immersive CAVE environments. Moreover, video game SAGEs have become attractive, even addictive, fixtures of popular culture and vehicles for commercially and politically-motivated "learning" (e.g. Skyworks Technologies, 2003; Soussi, 2003). Networked, collaborative simulation and gaming environments can provide these capabilities, offering needed interactivity, immersion, motivation, and a high degree of learner control as well as repeated practice, feedback and the opportunity for reflection where authentic experiential learning is infeasible for reasons of cost, access or safety (Johne, 2002; Kinzie et al., 1996; Rieber, 1996; Ruben, 1999).

Regarding learning outcomes and impact, evaluations and meta-analyses have shown mixed results for SAGEs but have produced many positive results. Garris et al. (2002) cite evidence of learning in three broad categories: skill-based (including technical and motor skills), cognitive learning (encompassing declarative knowledge, procedural knowledge, and

strategic knowledge), and affective knowledge (attitudes). Faria (2001) reviews learning in business simulations, concluding that simulation participants have been shown to learn basic facts and concepts, score better on course final exams in the majority of cases, feel positively about their perceived learning, and show some behavioural change. A number of studies have demonstrated the effectiveness of games and simulations for cognitive, emotional and psychomotor learning, notably Baranowski et al. (2003), Black (2001), Hourst and Thiagarajan (2001), Lederman et al. (2001), Lieberman (2001), Makuch and Reschke (2001), Sauvé et al. (2002a) and (2002b). According to these studies, games and simulations motivate learning, offer immediate feedback, consolidate knowledge, support skills development and application, aid learning transfer, and influence changes in behaviour and attitudes.

However, researchers report stumbling blocks which need to be further addressed through research. Hourst and Thiagarajan (2001) and Thiagarajan (1998) note that games and simulations are not tested as well as they should be in order to establish their technological performance, learning effectiveness, and efficiency. Bartholomew et al. (2001) argue that a lack of connection between theory and concrete, operational practices weakens the effectiveness of educational tools such as games and simulations. These analyses raise the question of whether divergent outcome results in game and simulation research could be caused by weaknesses in the theoretical frameworks of the studies, defective methodologies, or lack of connection between theory and practice. Moreover, we are only beginning to gain experience with, and evidence of, the impact of learning theory implementation using newer technology-based SAGEs. Our project will address the issues of creating guidelines for design and testing based on the context of use, within a framework of cognitive and educational theory and user-centred design specifically engineered for learning environments.

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. Key to doing this are rigorous evaluation methodologies that test evolving learning strategies and new, more complex learning environments (Grössler, 2001; Owston, 2000). Yet literature searches show that to date, most SAGE evaluations are merely descriptive papers (Kneebone, 2003; Letterie, 2002); many report only learner perceptions and address just the first level of Kirkpatrick's (1994) evaluation framework of learner reaction/ satisfaction, learning, behaviour change, and longer-term results. Moving beyond this level is difficult; Dempsey et al. (2002) observe that much of what occurs in a gaming environment involves complex cognitive processes that may not be easily measured or easily reduced to a few variables, and Grössler (2001) and Kneebone (2003) note that educational evaluation is constrained by our inability to control variables as well as the need to work within curriculum limitations and with limited opportunities for longitudinal study. However, SAGEs also offer possibilities for new data collection and analysis techniques; Kneebone (2003) states that "a key advantage of simulated practice is that it can collect performance data automatically, using objective "metrics" to build up a multifaceted picture of each learner's skill base. The development of such metrics is itself an emerging field, and there is as yet no uniform approach to measuring performance" (p. 273). We need extensive research to develop theory-based, rigorous evaluation tools and methodologies that are appropriate to these new learning environments; a particular aspect of our research will be to examine eye movement and physiological measures, which are informative with SAGEs and will provide a new window on how people learn.

Research questions and domains

Our research will investigate three broad sets of questions:

- **Understanding learning with SAGEs:** How does learning take place with SAGEs? What factors from cognitive psychology (e.g., context, engagement, metacognition); learning theory (e.g., motivation, feedback, reinforcement, communication, collaboration); psychology of perception; play theory; and related areas contribute to learning effectiveness in SAGEs? What can be learned from successful computer 'entertainment' games about creating 'learning' games, simulations, and simulation games? What can we learn from experience with non-technology-based games, simulations, and simulation games, and currently available ones?
- **Integrating theory and practice:** How can principles of learning theory and instructional design be incorporated into games and simulations to maximize their learning effectiveness? How can collaboration and learner support be effectively integrated into the SAGE learning cycle? How can SAGEs be implemented in ways that support their continued use and maximum benefits? How can organizational and cultural barriers to using SAGEs be overcome? What unique challenges arise in designing SAGEs for learning object repositories and how can these be overcome?
- **Methodologies and tools for SAGE research and evaluation:** What can we learn from existing evaluation tools and methodologies? What new tools and methodologies are needed to study SAGEs, and can we develop these? What meta-evaluation methods are appropriate for evaluating SAGE outcomes?

Our research focuses on SAGE applications in the health domain (for students of medicine and the health professions, health system managers, teachers, students, patients, community health workers, and the public) in order to build on the experience, expertise, and contacts of our team members, respond to a high priority for improving the health system, and health status of Canadians (important in the INE agenda), facilitate sharing of knowledge and generalization of results among team members and others, and, through our existing and future network of contacts, to facilitate testing and full-scale implementation of the SAGEs created in this initiative. Leading-edge technologies are being studied, including new tools on the Internet, CD/ DVDs, handheld computing devices, cell phones, and wireless technologies. The research is being done through projects in the three application domains of *games, simulation games*, and *simulations*, with three foundational domains on *methodologies and tools, conceptual foundations and technology* to support research by all the SAGE domain teams.

Application Domain 1: Learning with games. Many studies have looked at game characteristics and learning. For example, Bastuji-Garin et al. (1999) and Lieberman (2001), considering health games, list challenge, motivation, role models, simulation, repetition and feedback as crucial design factors for the development of improved self-esteem, self-efficacy, knowledge, and skills; the social context in which the games are played by young children and adults also helps them to develop communication skills and better social support for health-related behavioural changes. With the advent of the Internet, interest in the design and use of games in the context of learning has increased and seems a promising avenue for the integration of information and communications technologies with pedagogy (Johne, 2002; Sauvé, 2002; Sauvé et al., 2002a). Our work extends these studies to new environments, identifying and describing key attributes of new-technology educational games which contribute to learning.

We are examining three sets of dimensions central to our objectives:

- *game features that affecting learning*, such as levels of interactivity, levels of challenge, immediate feedback (system and human), levels of participation, customization, dialogue among users, and utility of what is learned and *factors affecting the acquisition and retention of knowledge;*
- *factors affecting attitude and behaviour change*, such as modeling, training, feedback and self-management, group dynamics, and knowledge of the stages of change;
- *factors related to the transfer of knowledge from expert to learners*, in particular the perception of utility of the games and the development of teaching/facilitation skills.

These variables, as well as the relationship among input, process and outcome variables, are being studied in the context of development of health promotion knowledge and skills for trainers in Canadian community settings as well as with elementary and secondary school teachers in Quebec and New Brunswick. (The effectiveness of similar interventions has been demonstrated in O'Loughlin et al., 1996.) They will also be studied in other contexts including public school classrooms and professional schools (medicine, nursing, physical therapy, pharmacy). We are studying existing frame-games on the Internet (Sauvé et al., 2001, 2002a) and develop and test new prototypes in the health field.

Application Domain 2: Learning with simulation games. Simulation games offer play, exploration, practice, and often addictive entertainment. Researchers and practitioners have argued for many years that play supports learning (Caillois, 1958; Piaget, 1969; Rieber, 1996; Rieber & Matzko, 2001; Wheatley, 1999), and current interest in educational gaming is often linked to a desire to harness the intense motivation and enjoyment that video game players experience (Garris et al., 2002; de Castell & Jenson, 2003). Garris et al. (2002) cite fantasy, rules/ goals, sensory stimuli, challenge, mystery and control as characteristics that contribute to "hooking in" players of commercial games; they and others hypothesize that these factors lead to improved learning outcomes. Some have also suggested that learning in immersive simulation environments is "stealth learning," taking place as a by-product of exploration, navigation, interaction, and absorption in virtual environments (Prensky, 2001; Seely Brown, 2002; Suter, 2002). In this domain, we are concentrating on (1) identifying factors in simulation games that lead to play, motivation, and immersion experiences, and their relationship to learning outcomes; (2) defining and evaluating the types of learning that actually occur in these environments, and (3) developing and studying an Internet-based simulation game that incorporates key features (as identified in our initial work) and can be used by individuals and by collaborative teams to solve dynamically developing planning scenarios in health related areas.

Application Domain 3: Learning with simulations. Research in this domain is concentrating on the use of technology-supported models of the "real world" to support health-related learning. One major application of simulations in health is problem-based learning (PBL), a pedagogical strategy for posing significant, contextualized, real world situations, and providing resources, guidance, and instruction to learners as they develop content knowledge and problem-solving skills (Barrows & Tamblyn, 1980; Mayo et al., 1993). PBL has been used in a wide range of diverse disciplines internationally and is the primary pedagogical model used with cases in the education of health professionals, particularly for physicians (Barrows, 2000), but also for education and continuing professional development in health professions (Foley et al., 1997). Although there is a strong rationale for the use of PBL (Kaufman, 1995; Kaufman et al., 2000, Norman & Schmidt, 1992) and students rate it as more effective, enjoyable, and satisfying than conventional methods (Kaufman, 1995; Schmidt,

1998), its impacts on student learning have been mixed (Albanese & Mitchell, 1993; Berkson, 1993; Finucane et al., 1998; Nandi et al., 2000; Norman & Schmidt, 1992; Schmidt, 1998; Vernon & Blake, 1993).

Some educators in the health domain have worked to increase the efficiency and effectiveness of PBL by providing resources on the web (Pankratz, 1998; Steinkuehler et al., in press), using asynchronous communication forums for discussion (Battistella et al., 2001; Kaufman, 2001; Tichon 2002), adding multimedia elements to print-based cases (Martindale, 2003; UPMC, 2003), or providing web-based PBL learning environments with multiple information and support features (CaMILE, 2003; Eisner et al., 2003; Lautenbacher et al., 1997). Very little research has been conducted on these extensions to the standard PBL model, although the few studies reported appear to support these developments (Pankratz, 1998). Although a number of educators have developed health-related simulations (some to support PBL), few have done rigorous research on their learning effectiveness. In this domain, we plan to review, adapt, create, apply and rigorously evaluate collaborative simulations in support of problem-based learning in health education in schools, universities and professional practice settings.

Metacognitive supports for learners are widely recognized as critical for learning with PBL and with SAGEs, whether incorporated into SAGE technology or offered by human facilitators. Leemkuil et al. (2003) list collaboration, instructional support, reflection, explication, and argumentation as key aspects of the process of learning with a management simulation. Other writers have described various aspects of the facilitator's role in metacognition (e.g., Asakawa & Gilbert, 2003; Hmelo & Day, 1999; Hmelo-Silver, 2002; Petranek, 2000). However, much of the research is descriptive, and more systematic study is greatly needed. Our research in this domain is systematically building in metacognitive supports and study their effects.

Methodology

Our research uses a multi-methodological approach (Abric, 1994; Tashakkori & Teddlie, 1998) consisting of descriptive, developmental, and evaluative research phases (Table 1):

Phase 1: Descriptive research

Research goals: (1) to create a comprehensive SAGE taxonomy and conceptual framework, (2) to identify and describe key SAGE factors which support learning; (3) to identify needs for new research methodologies and tools, and (4) in order to establish SAGEs as learning objects, to identify

Table 1. SAGE Research Phases

Phase 1 – Descriptive Research	Phase 2 – Developmental Research	Phase 3 – Evaluative Research
• Do comprehensive literature review • Build/refine SAGE taxonomy and conceptual framework • Identify needs and develop new methodologies and tools • Conduct research on existing SAGEs	• Design and develop prototype SAGEs • Test prototype SAGEs • Refine prototypes based on test feedback • Develop process to specify existing SAGEs as learning objects	• Develop methodologies and evaluate outcomes of refined SAGEs • Conduct rigorous research studies on SAGE in authentic contexts and evaluate

pedagogical specifications (CREPUQ, 2002; REFAD, 2002) and conceptual attributes of SAGEs (Locke et al., 1987) in order to develop a referential pedagogy appropriate for research on learning objects of this type and address the low priority often given pedagogical standards in the indexing of learning objects (Vachon, 2002). This phase is iterative and will continue throughout the four years of our initiative.

Methodology: For this work we are being guided by recent advances in cognitive science that are concerned with: (1) the representation and organization of knowledge; (2) self-regulation, metacognition, or change of agency for learning; and (3) the social and situational nature of learning (Bransford et al., 2000). Three basic threads of research will comprise this phase: (1) a synthesis of existing literature, consisting of systematic review and meta-analyses; (2) local studies of current, exemplary SAGEs: rigorous, small-scale studies of SAGEs clearly identified as highly engaging and widely used, e.g. The SIMS and existing SAVIE games; and (3) identification of needs for methodologies and tools. For (3), we will begin by delineating, in collaboration with domain leaders, the anticipated cognitive, metacognitive, and social skill outcomes of SAGEs across domains for various categories of learners (elementary and secondary level school students, postsecondary students, adult learners). These outcomes will be mapped to available assessment methods and tools found through an extensive search of the literature, gaps identified, and priorities established for our research.

Phase 2. Developmental research

Research goals: This phase uses a developmental strategy (Contandriopoulos et al., 1990), applying existing knowledge to systematically improve the use of SAGEs for the target populations. Five prototypes will be created, based on the results of Phase 1:

1. a prototype Internet-based generic game shell, specifically for the health field. The frame-game methodology (Hourst & Thiagarajan, 2001; Sauvé & Chamberland, 2003; Sauvé et al., 2002; Stolovitch & Thiagarajan, 1980), tested for non-computerized games, will be used to provide a structure offering conflict and rules and criteria for declaring a game winner;

2. an Internet-based educational simulation game, "Contagion," for the 9 to 12 year old age group, consisting of a component within an existing web-based environment, *Ludus Vitae* (de Castell & Jenson, 2003). Integrated into the *Ludus Vitae* framework as proposed here, the game, "Contagion" will offer a number of activities and supports for learning including anonymity, conducive to increased learner participation (Bell, 2001; McLaughlin & Kirkpatrick, 1999), and role play using accomplished virtual role models, associated with attitudinal and behavioural outcomes (Bell, 2001; Collins et al., 1989);

3. simulation game scenarios using handheld devices that mimic geographic and real time factors and allow individuals to use their own handhelds to manage role playing within simulations based on networks of physically separated information stations;

4. simulations integrating multimedia, role-playing, and virtual patients (Lane et al., 2001) to support problem-based learning. Based on actual or adapted clinical cases (e.g., Martindale, 2003; UPMC, 2003), these simulations will address issues around health promotion, diagnosis, treatment and management. Their technology elements includes multimedia (e.g. videos, images, sound, animation) and web support with synchronous voice-over (e.g., Elluminate, 2003) or asynchronous (e.g., WebCT, 2003) communication.

Phase 3. Evaluation research

Research goal: In this phase we will rigorously evaluate, using our prototypes, learning outcomes and the relationships among input, process and outcome variables in the conceptual framework. However, our primary focus here will be on developing new methods and tools where major gaps are identified. Emphasis will be placed on both formative and summative assessment tools and their interrelationship. All tools that do not have an established history of use will be pilot tested and revised where necessary. Tools will be made available to project researchers once they have been reviewed by researchers in this project.

Methodology: Our evaluation research uses a combination of traditional and recently developed research methods as appropriate for individual prototypes, including experimental and quasi-experimental research studies (Campbell & Stanley, 1996), case study approaches (Stake, 1995; Yin 1994), grounded theory (Strauss & Corbin, 1998), participatory action research (Kemmis & McTaggart, 2000), mixed quantitative-qualitative models (Tashakkori & Teddlie, 1998), and Web-based learning models evaluation (Owston, 2000). From this literature, a framework will be developed that recommends to theme researchers models for use that map to their specific research goals. Also, two innovative aspects will be integrated into the evaluation:

Instruments: Various data acquisition and analysis instruments will be used. We will use a trace system to record learner actions on the web sites, recording of perceptual and physiological changes, social network analysis, audio and video recording of interviews and focus groups, tests of cognitive and social learning, online and face-to-face observation; existing online questionnaires on learner characteristics (Sauvé et al., 2002a), and others i.e., learning style (Entwistle & Hilary, 1995; Grasha, 1990; Kolb, 1976), motivation (Viau et al., 1998), conditions and modes of learning (Canfield, 1980), online interviews, focus groups, and questionnaires. We also will conduct achievement tests in appropriate contexts to assess immediate learning, transfer and retention. Finally, we will follow up with participants in practice settings, e.g., physicians, nurses to determine if their behaviour has changed.

Expected Outcomes

This research will not only synthesize SAGE research for the community at large, but it will also help shape future SAGE research programs as new findings come to light and gaps are identified. A number of important outcomes are expected to arise from this collaborative research initiative:

- a multidimensional taxonomy for clarifying the literature across the wide range of SAGE types;
- identification of inputs and process factors related to learning outcomes in order to guide our development of effective future learning environments;
- increased knowledge about the learning process and outcomes that occur in different settings, with different types of learners and with various technologies;
- case examples of how SAGEs can be used in schools, workplaces, and community settings to improve health education and health promotion;
- specifications for SAGEs which address standards for indexing of learning objects for access and use by learners and teachers;
- guidelines and methods for (1) SAGE design and testing within the context of learning situations, goals, and models; (2) adaptation of educational methods to include SAGEs; (3)

selection of effective, complementary SAGEs and instructional methods, and (4) training of Highly Qualified People in SAGE research.

Conclusions

The SAGE for Learning project has been funded for two years. Significant progress has been made toward the research objectives outlined above. However, the key phase of evaluation research remains to be conducted in various settings, and we look forward to examining the impact of our SAGE prototypes.

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