Simulation and Advanced Gaming Environments (SAGE) for Learning: A Pan-Canadian Research Project

Project objectives

The purpose of the four-year , $3million, "Simulation and Advanced Gaming Environments (SAGEs) for Learning" INE Collaborative Research Initiative 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 develop and test *methods for specifying SAGEs as learning objects* for standards-based repositories;
- 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 complementary SAGEs and instructional methods using our new taxonomy, and (4) training of Highly Qualified People.

Research on the pedagogical impact and effectiveness of new-technology SAGEs is rapidly developing internationally (e.g., DiGDA, 2003; Digiplay, 2002; EU-GAMERESEARCH-NET, 2003; IDEELS, 2003; MIT, 2002); however, Canada has few projects in this area. Canada has a number of skilled and successful video game development companies (e.g. see Rockel, 2003), but very little research has been conducted here on SAGE learning impact. Our work will focus Canadian resources and expertise on the above objectives, position Canadian researchers as active participants in this growing field, and establish mutually useful relationships among researchers and major simulation and game developers. Our proposal 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 will be an added benefit; in particular, this will make 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., 2002). Finally, we plan to leverage 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; Thiagarajan, 1998). 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; Lieberman, 1998; Nehring et al., 2001; Powell, 2001; Renaud & Stolovitch, 1988; 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; examples include AIDA, a diabetes patient simulator used with patients and medical professionals (Lehmann, 1998; Tatti & Lehmann, 2001); the HEART-SENSE Game for improving recognition of heart attack symptoms and reducing treatment delay (Silverman et al., 2001); the simulation "I take drugs; step into my shoes" for demystifying the social world of drug users in nursing education (Norman, 2001); an Internet-based patient simulation engine and immersive virtual reality environment to support medical school problem-based learning at a distance (Jacobs et al., 2003); and numerous other applications for clinical, surgical, and interpersonal skills development (Lane et al., 2001).

The terms "game" and "simulation" are used somewhat interchangeably in the education and gaming literature, although researchers have attempted to differentiate them and to describe specific characteristics of each which affect learning (Crookall et al., 1987; Garris et al., 2002; Leemkuil et al., 2003; Maier and Grössler, 2000; Sauvé, 1985; Schmucker, 1999; Stolovitch, 1981). Following Crookall et al. (1987), Garris et al. (2002), and Stolovitch (1981), we distinguish among three broad types of activities: (1) *games* - activities that do not attempt to replicate reality, have clearly defined sets of rules including scoring systems, and produce winners and losers; (2) s*imulation games* - games that are based on simplified but dynamic models of aspects of reality, and (3) s*imulations* – activities that include exploration and practice within models of reality but without competition, scoring, and winners/ losers. We believe that this distinction will be useful in creating a conceptual framework that describes and distinguishes these SAGEs.

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 example, 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)).

These environments would seem to offer unparalleled opportunities to support and extend what we know about learning effectiveness. Constructivist learning theorists argue that learners need context within which to explore, discover, communicate, practice, and create their own understandings of complex phenomena (Boethel & Dimock, 1999; Vygotsky, 1978). Motivation to learn and to participate actively in learning communities is influenced by both the relevance and utility of the learning, and by learner enjoyment (D'Alessandro & Kingsley, 2002; Wlodkowski, 1985). Skill development is advanced by "learning by doing" including practice and feedback, with "failure" in a "safe" environment (with learning supports) being important for learning (Schank & Neaman, 2001). Social cognitive theorists suggest that positive role models and opportunities for successful experiences help to develop self-efficacy and positive attitudes concurrently with knowledge and skills (Bandura, 1986; Kaufman et al., 2000); reflection in practice and reflection-on-practice are seen as essential to the development of metacognitive skills and to the continual development of expertise (Dobson et al., 2002; Kaufman et al., 2000; Schön, 1987). 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; St-Germaine & Leveault, 1997).

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), Bartholomew et al. (2000), Black (2001), Hourst and Thiagarajan (2001), Jones (1998), Lederman et al. (2001), Lieberman (2001), Makuch and Reschke (2001), Sauvé et al. (2002a) and (2002b), Renaud and Stolovitch (1988), Reuss and Gardulski (2001), Ripp (2001), Ross et al. (2001), and Shapiro & Shapiro (2001). 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. Alessi and Trollip (1991) and Thurman (1993) argue that educational games and simulations developed with information and communications technologies are often badly designed and present ineffective learning environments. 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.

To fully understand and improve learning with SAGEs, then, 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 (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 phases and domains

Our research will be conducted in three phases: (1) Understanding learning with SAGEs; (2) Integrating theory and practice and (3) Methodologies and tools for SAGE research and evaluation. Our research will focus 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). Leading-edge technologies to be studied will include new tools on the Internet, CD/ DVDs, handheld computing devices, cell phones, and wireless technologies. The research will be done through projects in the three domains of *games*, *simulation games*, and *simulations*, with a supporting project on *methodologies and tools* to support research by all the SAGE domain teams.

Projects will be grouped as follows:

Conceptual Foundations. This integrative project will review the literature comprehensively and will develop a conceptual framework to describe the field of SAGEs.

Domain 1: Learning with games. This domain will extend previous studies to new environments, identifying and describing key attributes of new-technology educational games which contribute to learning.
Domain 2: Learning with simulation games. In this domain, we will concentrate 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. We will also investigate the potential of handheld devices to support effective learning with simulation games.
Domain 3: Learning with simulations. Research in this domain will concentrate on the use of technology-supported models of the "real world" to support health-related learning. 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.
Methodologies and Tools. This domain will address the design, development and use of new methodologies and tools for conducting research on SAGEs.

Project schedule and integration
Research in this project will be integrated through common research questions, a common health education focus, and the common conceptual framework. Work in the three domains will also share support and results from our research into methodologies and tools. Projects will be managed to ensure integration across time; the projects will share their knowledge according to a common timeframe and clearly defined deliverable dates so that knowledge gained in each project will be accessible and applicable to the others. All major documents and the project website will be published in Canada's two official languages – English and French. A process for individual accountability to the team will be developed collaboratively to ensure that all projects receive the benefits of knowledge created in the other projects. In other words, a SAGE community of practice will be created which will be supported according to best practices in this area.

Expected outcomes in the first 21 months
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;
- guidelines from the literature for 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;
- at least 16 papers submitted for publication
- at least 16 conference workshops and/or presentations
- a comprehensive website with member and non-member sections (see below).

Continuous Quality Improvement
A Continuous Quality Improvement (CQI) process will be integrated into the SAGE Collaborative Research Initiative throughout the project in two ways. First, a *monitoring evaluation* will be conducted by students external to the project, who will interview all participants regularly. This will be done throughout the project, and will result in semi-annual reports. Second, an External Advisory Panel will provide advice to the Staff and Executive Committee

Communication of Results
As our research progresses, we will use a multifaceted strategy to ensure effective internal and public knowledge sharing. A key tool for our communication and dissemination will be a bilingual *SAGE knowledge management web site* with public and members' areas.
SAGE Knowledge Management Website. The website will provide support to our researchers, partners and students by providing:

- a collection of "members-only" resources
- virtual (online) internal research workshops, beginning in Year 2
- links to SAGE sites worldwide
- a comprehensive online bibliography for the SAGE field, searchable by various search criteria, including keywords;
- abstracts of numerous publications available to non-members;
- listings of SAGE resources such as software tools.
- online games and simulations repository
- a collection of publicly-accessible, research-oriented resources on our web site, including working papers, preprints, and links to other research groups and relevant sites;
- periodic public webcasts with presentations and discussion for all interested participants.
- publicly accessible, non-technical resources on our web site, including short commentaries and position papers, useful web links and success stories about particular research projects;

Scholarly Dissemination and Communication
A variety of vehicles will be utilized for knowledge translation, including:

- Publications in peer-refereed journals, presentations at scholarly national and international *face-to-face conferences*, open to all interested participants.

Specific means of communicating beyond our website will include:

- a regular online and print-based newsletter with practical applications emphasized for the non-academic community;
- an online monograph summarizing research and development output for all fellow-professionals and policy makers.

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