EPISTEMIC LEARNING:

GAME PROGRAMMING LEARNED FROM THE LENS OF PROFESSIONALS

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Abstract

This study sought to determine the practicality and effectiveness of an alternate instructional approach referred to as epistemic learning – a low structured, high functioning environment where students learn the principles of practice (i.e., the epistemic frame) of a profession through role-play. This research on epistemic learning is integral in assisting educators to enhance learning and accomplish instructional goals in computer science by having students acquire the epistemic frame of a computer game programmer. Currently, literature on epistemic learning is sparse due to its nascent nature.

An action research design with mixed-methods analysis was utilized to assess students' responsiveness to epistemic learning through an examination of their personal epistemological growth, epistemic frame construction, and programming skill set development. Personal epistemological growth was assessed through a self-reporting epistemic beliefs survey that established students' attitudes about knowledge and learning. Epistemic frame construction was established using epistemic network analysis in determining the specific epistemic frame characteristics students had acquired. Teacher observations and students' reflections provided insight regarding programming skill development.

Findings revealed the following: 1) each student's personal epistemology was positively influenced through epistemic learning; 2) most students successfully acquired the complete epistemic frame of a game programmer; and 3) students' computer programming skills were enhanced through epistemic learning. Although a statistically significant correlational relationship was not established, the results had practical importance as they indicated that students were prepared to participate and succeed in an environment that emulates professional practices. Future research should include longitudinal studies that implement epistemic learning.

Keywords: epistemic learning, epistemic frame, epistemic beliefs, personal epistemology, epistemic games, game programming, game-based learning, computer science

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Chapter 1: Introduction

Most educators would agree that technology has had a profound effect on today's youth as it offers them a viable tool that accommodates different learning styles through highly adaptive environments, supports active learning through a variety of interactive mediums, and enhances collective intelligence through networking. The influences that technology has placed on today's learners have made teaching them a challenge as they do not think or learn like their predecessors (Lankshear & Knobel, 2008; Massy & Zemsky, 2004; Prensky, 2001) nor do they respond to the more traditional approaches to teaching that are common in many schools (Brown, 2002; Friedman, 2007; Johnson, 2006). Current educational innovation will require that consideration be given to the development of next generation learning environments that better prepare students to respond to the changing ideas, attitudes, and technologies of their local and global communities (Gee, 2008; Johnson, Adams, & Cummins, 2012; Manitoba Education, Citizenship and Youth, 2006; Squire, 2005).

The broad topic of importance for this study is the promotion of instructional effectiveness through teaching practices that engage today's learner. Germane to the discussion of improving instructional effectiveness are four issues:

1. The changing nature of the digital age learner.
2. The influence of personal epistemology or epistemic beliefs on learning.

3. Epistemic learning as a next generation learning environment.

4. Current trends in curriculum policy and procedures pertaining to teaching and learning in the digital age.

Many educators would agree that successful teaching is often contingent on understanding their students and their needs (Gruwell, 1999; McCourt, 2005). The integration of technologies into educational environments has placed constant pressure on teachers to rethink their pedagogies in creating highly adaptive learning contexts that acknowledge and respect the learning differences of the technologically influenced learner. In recognizing that today's learners experience learning differently and possess diverse beliefs about learning, teachers are more likely to question their long-established educational practices and begin adopting strategies that engage digital age learners.

Improving instructional effectiveness requires that educators think creatively about their teaching practices. One such innovative next-generation learning environment is epistemic learning[1]. Epistemic learning is introduced in this thesis to mean a pedagogical approach that has, as its nucleus, the construct of epistemic framing – a way of learning through the lens of a professional or practitioner in a socially-accepted practice. Although it is not an entirely new idea, it does represent an alternative way of thinking. In acknowledging that digital age learners require literacies beyond

[1] First articulation of epistemic learning is credited to Dr. Francine Morin of the University of Manitoba.

reading, writing and numeracy, many provincial curriculum documents provide both pedagogical and instructional strategies to assist teachers in educating and preparing students for the future (Manitoba Education, Citizenship and Youth, 2004, 2006; Ontario Ministry of Education, 2002).

To assist in focusing this study and to provide perspective regarding the need for improved instructional effectiveness, the following sections will elaborate on the changing nature of the digital age learner, the influence of epistemic beliefs on learning and learning in an environment structured on epistemic framing. To address local initiatives in educating today's youth, consideration will be given to the Manitoba Literacy with Information and Communication Technology and Computer Science curriculum documents (Manitoba Education, Citizenship and Youth, 2004, 2006).

The Changing Nature of the Digital Age Learner

The Digital Age Learner

Prensky (2001) initially characterized the digital age learner as the digital native – an individual who is used to the instantaneity of hypertext, downloaded music, mobile technologies, web-browsing, and instant messaging. Massy and Zemsky (2004) described the digital age learner as an individual who wishes to be networked to others, expects to be entertained by music, games and movies and prefers activities that involve a complex representation of self. Many of today's students come to our classrooms with mindsets that have been shaped by their interactions with the Internet via cyberspace (Lankshear & Knobel, 2008; Wilen-Daugenti, 2007). Current research in neuroplasticity asserts that the minds of today's learners actually develop differently because of their exposure to digital technologies and media (Small & Vorgan, 2008).

Most recently, the Kaiser Report on Media 2010 (Rideout, Foehr, & Roberts, 2010) reported a huge daily increase in digital media use amongst youth over the last five years, from 6 hours and 21 minutes to 7 hours and 38 minutes. According to the Young Canadians in a Wired World survey (MNet, 2005), a Grade 11 student spends 8 hours and 19 minutes involved in online activities on an average school day – the equivalent to a full time job. The digital age learner's growing dependency on digital media for stimulation, information, education, and entertainment has become unparalleled and has consequently redefined how s/he learns (Aurilio, 2010). For these individuals, learning has become less about knowledge or being told what to think and more about acquiring lifelong learning skills or being taught how to think.

Lifelong Learning and Lifelong Learners

Technology has served as a catalyst for altering the way the minds of today's learners develop and function (Small & Vorgan, 2008). Subsequently, it has transformed the way today's students think and learn and has created a situation where "students are no longer the people our education system was designed to teach" (Prenksy, 2001, p. 1). Prensky, Small and Vorgan attribute the shift in thinking patterns to the ubiquity of digital technologies and the volume of interactions that today's learners have with those technologies. This is a reasonable claim as learners are influenced by their environment.

Traditionally, students have participated in an educational model that focused on mass education and training (Longworth, 2003). The influence that technological advances have placed on our society has resulted in constant pressure being exerted on the educational system to adopt a paradigm that focuses more on the development of lifelong learners. In the lifelong learning model (LLLM), students acquire the skills that will allow them to compete and function in the global community. In this model, the goal of learners is not only to improve their own lives but to look outward to the world and improve the lives of those in their community.

Learning is most often successful when it is closely related to a person's developing needs, is relevant to his/her circumstances and is purposeful. The LLLM endeavors to create a successful learning environment by shifting ownership of the need to learn and its content from the teacher to the learner (Collins, 2009). Ownership of learning does not necessarily mean the learner decides the content of the curriculum. Rather, it provides learners with the opportunity to provide their assent to the curriculum (Longworth, 2003). In such a model, individual agency empowers learners to contribute to the learning agenda in determining what they need to learn and how they are to learn. Engagement in learning is often enhanced when children have the opportunity to learn on their own terms rather than always being told what to learn.

By nature, children generally enjoy playing and learning. Learning is rewarding for children as long as they are successful at it. Lifelong learning promotes success as it is inclusive of all and is structured to confirm progress and encourage further learning. As Longworth (2003, p. 49) opines, “the concept of failure has no place in lifelong learning climate, where the objective is to switch people into, not off, continuous learning.”

Most notably, lifelong learning optimizes individual differences in learning and enables the learner to acquire the necessary skill sets to deal with unfavorable past experiences (e.g., failing a course) and unlearn or correct negative habits or behaviors (e.g., stealing cars). The emphasis in lifelong learning is that all can learn given the opportunity and the supports.

Epistemic Beliefs

Research on levels of development and structures of learning supports the notion that students of low structure environments (e.g., discovery learning) function at higher knowledge levels (Chang & Tsai as cited by Evans & Ravert, 2007). The discussion of improved instructional effectiveness cannot be addressed without first discussing learners’ personal epistemology or epistemic beliefs. Personal epistemology refers to the attitudes and beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs (DeBacker et al., 2008). An examination of epistemic beliefs is integral to this study as it will assist in answering the question: How do a student's attitudes and beliefs about learning influence their learning?

Schommer (1989, p. 7) categorizes epistemic beliefs along a continuum according to five dimensions:

- Simple knowledge – Beliefs about knowledge ranging from knowledge is discrete, compartmentalized facts to knowledge is complex and integrated.
- Certain knowledge – Beliefs about knowledge ranging from knowledge as concrete and absolute to knowledge as tentative and constantly evolving.
- Quick knowledge - Beliefs about learning ranging from learning happens quickly or not at all to learning is gradual and takes time and effort.
- Innate knowledge – Beliefs about learning ranging from the ability to learn is unchanging and fixed at birth to learning is acquired through experience, hard-work and self-improvement.
- Omniscient knowledge – Beliefs that learning is handed down by omniscient authority to learning that is derived by reason.

Students with simple or naïve beliefs about knowledge are more likely to experience poorer academic performance as they might view knowledge as being absolute, literal, handed down by authority, acquired quickly or not at all and/or as something that is fixed at birth (Bendixen & Hartley, 2003; Schommer-Aikins as cited by Greene & Azevedo, 2007). In contrast, individuals with sophisticated epistemic beliefs perceive learning to be a process of rational thinking, and knowledge as something that is constantly evolving (Kienhues, Bromme, & Stahl, 2010; Tutty & White, 2005). Through education, students' thinking can be developed towards a more complex position on knowledge (Evans & Ravert, 2007). This research intends to demonstrate that students possess a pre-existing complex personal epistemology and thus are prepared to participate and succeed in low structure, higher knowledge learning environments.

The Epistemic Frame

Teaching digital age learners presents a challenge as current educational instructional practices are often inconsistent with digital mindsets. The conventional practices of lecturing to an entire class and/or completing a curriculum before mastery is achieved have become counterintuitive to the manner in which today's youth learn.

In my situation, I was a pre-digital age instructor struggling to teach a population that spoke an entirely new digital language (Prensky, 2001).

Having taught information technology (IT) and information communication technology (ICT) courses for almost a decade, I have been immersed in what I consider to be a technologically amplified environment. Teaching digital age learners required a paradigm shift on my part in recognizing that for today's learner, knowing was doing and knowledge was primarily a set of activities and experiences (Cook & Brown, 1999; Gee, 2005; Orlikowski, 2002). This being realized, I began my search for instructional effectiveness. Two notable experiences taught me that there was value in organizing learning activities consistent with the digital mindset.

By framing a learning activity in the context of publishing a newspaper, my students learned numerous aspects of publishing including word processing skills, typesetting, copy-editing, and reporting. While their individual depth of knowledge varied, their collective depth of knowledge was both extensive and impressive. Enculturation into the practice of newspaper publishing required that the students also assumed responsibility for task allocation, contribution to design and detail, and collaboration on newspaper layout and other editorial issues. Through the restructuring of learning activities as complex holistic problems (real-life problems) within a knowledge domain (newspaper production), my students successfully acquired the knowledge, skills, identities and values of a community of practice (Shaffer, 2004).

On another occasion, my IT students assumed the role of network technicians whose responsibilities included designing, configuring, and implementing a local area network (LAN) within the classroom. The knowledge and skill set required to undertake such a task is substantial and beyond the level of most high school students.[2] However, when functioning as a collective where individuals pooled their resources, the task became less daunting. From this experience, students were able to organize LAN parties at their homes for the purpose of playing multiplayer networked games. Operating as a cohesive unit taught these students to think and act in accordance with a role that might otherwise be inaccessible and, in the process, enabled them to develop effective social practices (Network Analyst, 2010).

At its core, the design of the learning environment I experimented with focused on learning through enculturation. Enculturation ("Enculturation", n.d.) is described as a process of learning the requirements of a culture and acquiring the values and behaviors necessary for membership in that culture. Members of the culture learn to examine problems from a practitioner's or professional's perspective and to apply their skills and knowledge to existing or new situations (Lombardi, 2007; Nash & Shaffer, 2008; Sherry & Trigg, 1996).

Educational settings structured on enculturation take the form of labs, studios, or workplace situations where individuals learn through peripheral participation that extends beyond normal school experiences (Brown, 2006). The intent of enculturation is not to create professionals but rather to provide

[2] When the students were creating the networks, the technology of that time did not have the sophistication of today's technologies. Consequently, students were required to have a greater skill set in configuring networks.

students with the opportunity to think in creative and innovative ways in developing their intellectual toolkits.

Learning through enculturation is synonymous with learning through the lens of an epistemic frame. Shaffer and colleagues (2004) define an epistemic frame as the organizing principles of a community of practice (i.e., skills, knowledge, values, identity, and epistemology[3]). Once learned, these elements shape how an individual thinks, acts and practices as a member of the community (Shaffer et al., 2009). For example, lawyers, teachers, and biologists all have distinctive epistemic frames that govern the ways of knowing, of deciding what is worth knowing, and of adding to the collective body of knowledge and understanding of their respective practices.

Svarovsky (2009) defines an epistemic frame to be a metric for professional expertise where the strength of the epistemic frame depends on an understanding of its individual elements and the relationship between its elements. In the context of this thesis, engagement in the process of learning through an epistemic frame will be referred to as epistemic learning.

Epistemic Learning

Epistemic learning constitutes learning through a post-progressive pedagogy – a pedagogy that combines immersion with well-designed guidance (Brown, Lehrer, Lehrer & Schauble, & Martin as cited by Gee, 2008). Through epistemic learning, "students are engaged in real work, fully

[3] In the context of an epistemic frame, epistemology refers to a community's ways of making decisions and justifying its actions (Shaffer, 2007).

participating in the technical and social interchanges and almost through osmosis are picking up not only the practice, but also the set of sensibilities, beliefs and idiosyncrasies of this particular community of practice" (Brown, 2006, p. 7).

Epistemic learning can be described as a process of learning the organizing principles of practice through a coherent activity system where knowledge is treated primarily as activity and experience and factual learning occurs purposefully as it is needed in-context (Shaffer, 2006). Students learn the principles of practice (i.e., epistemic frame) of a community through an intentional process of solving well-ordered problems meant to help them understand how the community members think and respond. As students develop a more robust epistemic frame, learning in the community of practice becomes more intuitive (Svarovsky, 2009).

Epistemic learning involves participating in activities that simultaneously align the interest of the learners, the structure of a domain of knowledge, valued real world practices, and modes of assessment (Shaffer & Resnick, 1998). In the context of knowledge, epistemic learning extends beyond learning *that* (declarative knowledge) and learning *how* (procedural knowledge) to encompass learning *with* (Shaffer, 2007).

Epistemic learning shares many of the same characteristics as situated learning, distributed authentic professionalism, and/or thickly authentic learning (Lave & Wegner, 2008; Lombardi, 2007). However, it distinguishes itself from other pedagogies as it is theoretically underpinned by digital learning principles and fosters learning through practices that parallel professional role-play. The digital learning system serves to support and justify our use of technologies in the classroom through theories of learning relevant to technology-based education, its accompanying methods of assessment, and inclusion of an evidence-based, digital intervention while simultaneously addressing learning for a new age (Shaffer et al., 2009). Professional role-play encourages real-world learning by engaging students in learning through mentorship relationships, completing tasks that align real-world practices and core skills, and allowing individuals to fully participate in a community of practice.

While epistemic learning draws on different pedagogical approaches, its distinguishing characteristics qualify it as a pedagogy that stands apart from others. In contributing to the advancement of learning, this thesis endeavors to add epistemic learning to the educational landscape and to its vernacular.

Policy, Procedures and Curriculum

Various provincial education ministries have implemented policy, procedures and curriculum designed to educate digital age learners in the reasonable and responsible use of technologies (Manitoba Education, Citizenship and Youth, 2004, 2006; Ontario Ministry of Education, 2002). For example, the *Manitoba Seniors Years ICT Curriculum Framework* and the

Manitoba Curriculum Framework of Outcomes for Computers Science 20S, 30S and 40S, specifically stress the need for today's learners to be more self-directed and to develop lifelong learning skills (Manitoba Education, Citizenship, and Youth, 2006).

> Students must become independent learners if they are to maintain their skills and understanding of ICT. Products and techniques continue to evolve. Students are expected to learn new information and continually adapt to changes. To ensure that students become lifelong learners, it is imperative that they become increasingly engaged in planning, developing, and assessing their own learning experiences. They must have opportunities to work with other students, to initiate investigations, to communicate their findings, and to complete projects that demonstrate their learning. (p. 4)

Statement of the Problem

The overarching goal of this study is to contribute to educational pedagogy through the examination of a next-generation learning environment that engenders practitioners' habits of mind through situational learning in an accepted social practice or profession. This need extends to include an analysis of environments that emulate the form of inquiry and practice conceived in virtual worlds as these worlds allow learners to experience abstract ideas as concrete realities (Shaffer et al., 2004). A gap in research literature would suggest the need exists to examine such environments as they may have the potential to improve instructional effectiveness.

Many, if not most, of today's teachers have spent years constructing their ideas, viewpoints, and beliefs about education from teachers who practiced in a different era (Aurillo, 2010). To compound issues, today's teachers struggle to use technological tools and labor to comprehend how these technologies influence the current learners' perspective on knowledge and learning. While today's teachers look to the past to inform their teaching and learning, today's learners look to the future to guide their learning. The more conventional approaches to teaching and learning have generally served students well in the past. However, today's student sometimes becomes lost in the rigid and less responsive educational systems and requires alternate means of learning (Schilling, 2008).

Immersive environments that recruit participants into assuming new identities support learning by enabling participants to acquire the ways of practicing, thinking and acting in a community of practice. These role-playing environments are highly engaging for learners as they are situated, social and require a high degree of personal agency (Aurillo, 2010). Learning experiences within this setting are structured to help learners understand phenomena by working with holistic complex problems initially rather than by mastering isolated facts and skills that then need to be assembled into conceptual building blocks and at a later time applied to problem solving

(Shaffer, et al., 2009). Virtual and/or real epistemic learning constitute different approaches to creating an immersive environment.

Purpose of the Study

This study seeks to determine the practicality and effectiveness of an epistemic learning environment. Epistemic learning in this study will constitute learning computer science through the epistemic frame of a computer game programmer. Study findings are expected to demonstrate that by structuring learning through epistemic framing, students will begin to think and behave in a fashion similar to practitioners in the game programming industry. Epistemic learning occurs as an individual, in the role of a member of a community of practice, increasingly engages in activities that define that community and its purpose (Shaffer, 2004, 2006). For epistemic learning to be more authentic, it would require that students be immersed in the actual professional occupation or social practice. Outside of vocational and business programs, schools struggle to create learning environments that provide immersive practicum-based experiences. This study will endeavor to create a reasonable reproduction of a computer game programmer practicum to stimulate epistemic frame construction within that community. It is anticipated that the study will demonstrate the feasibility of such initiatives in very limited environments.

Objectives of the Study

The objectives of the study are to:

1. Establish that digital age learners possess different epistemic beliefs regarding knowledge and learning;
2. Demonstrate that learning in an epistemic learning environment can be an effective instructional strategy;
3. Identify the epistemic frame qualities acquired by students, individually and as a collective, through each iteration of the action research cycle;
4. Assess the impact on learning in an epistemic learning environment, and
5. Contribute to the research on emerging instructional strategies.

If it can be demonstrated that epistemic learning is a viable alternative approach in educating today's youth, teachers can begin or continue to verse themselves in instructional methodologies designed for digital age learners.

Research Questions

This study seeks to answer the following research questions:

1. How does epistemic learning influence epistemic beliefs?
2. Which computer game programmer's epistemic frame qualities are acquired through epistemic learning?

3. How does an epistemic learning environment enhance learning in computer science?

The research questions will be answered in the context of an action research project. This research methodology was selected as epistemic learning is a gradual and persistent procedure as is the case with most learning. In answering research question #2, consideration will be given to both individual and group advancement. This is significant to the study as epistemic framing involves both an individual and group dynamic.

Significance of the Study

The importance of undertaking this study is predicated by the apparent lack of research on next-generation learning environments and evolving pedagogies. This study is expected to contribute to a nascent body of educational research that investigates learning in the digital age in the context of the epistemic frame of a community of practice. Adopting the "ways of doing, acting, and thinking" of a community of practice facilitates in learners the capacity to be self-directed problem-solvers of concrete and personally meaningful tasks. It is anticipated that the study results will inform teachers in similar educational contexts in matters concerning their learning and teaching of computer science.

Scope of the Study

The primary issue of investigation in this study is the educational potential of an epistemic learning environment. This study seeks to determine if students enrolled in a Grade 11 computer science course in a suburban high school can learn computer science through engagement in an environment that is comprised of the following characteristics: (1) sound digital learning principles that support current learners' mindsets (Gee, 2008, Sword & Leggott, 2007), (2) game programmer role-play activities that amplify the learning experience (Coad, 1995; Johnson, 2006), and (3) simulation to expand the range of what students can realistically do, the worlds they can inhabit, and the obstacles they can overcome (Ibbitson & Irvine, 2005; Lombardi, 2007). More succinctly, can students learn computer science by practicing, thinking and acting like game programmers? This study will endeavor to answer the question through observation of students' experiences and assessment of individual and group development as participants engage in the design, construction, coding and beta-testing of a 3D computer game.

Since the study will monitor both the individual and group dynamic of epistemic learning, it will be deemed that individuals have acquired an epistemic frame trait if they repeatedly demonstrate the quality. Group progression will depend on convergence towards an epistemic frame quality. Since there is interdependence between the epistemic frame elements, the study will attempt to identify the relationships that exist between elements as they arise.

The study was conducted in the first semester of the 2011-2012 school year. The duration of the study was 9 weeks (45 days) commencing in late October and ending in early January. It was necessary to extend the study an extra week because students lost work time due to technical difficulties with the divisional server. The lost work time did not adversely affect the research.

Summary

Technology has significantly influenced the physiological and intellectual development of the minds of today's youth. Digital age learners have become evolved learners who have different beliefs about learning and think and process information in ways that may seem foreign to many educators. As students' minds evolve, so must the learning environments and teaching pedagogies. Epistemic learning represents an alternative instructional model that may enhance learning in students, especially with respect to computer science. Epistemic learning utilizes the epistemic frame of a community of practice to encourage students to develop the mindset of that community and experience learning from a situational perspective. By structuring learning through the lens of an epistemic frame, it is anticipated the findings of this study will demonstrate that students respond positively to epistemic learning and that this instruction model has educational potential.

Definition of Terms

Amplified learning environment - An environment that seeks to effectively use core intelligences (mathematical-logical and linguistic) with amplifier intelligences (spatial, musical, bodily-kinesthetic, intrapersonal, and interpersonal) to enhance the learning experience (Coad, 1995).

Attentional deployment – The ability to focus on several things at the same time, and being able to respond faster to unexpected stimuli (Prensky, 2006).

Bricolage - A concept having to do with one's abilities to find something that can be used or transformed to build something new (Brown, 2002).

Community of practice – A group of individuals who share a repertoire of knowledge about and ways of addressing similar and often shared problems and purposes (Lave & Wenger, 1991).

Distributed cognition – The sharing of cognitive resources by a social group in overcoming problems that cannot be solved individually (Distributed cognition, 2008).

Epistemic - Relating to knowledge or epistemology and the conditions for acquiring it (Epistemic, 2013).

Epistemic beliefs - Refers to personal beliefs about knowledge and knowing to include: 1) the nature of knowledge (certainty of knowledge and simplicity of knowledge); and 2) the nature of knowing (source of knowledge and justification of knowledge) (Evan & Ravert, 2006).

Epistemic frame – A theoretical construct used to describe the collection of skills, knowledge, identity, values, and epistemology that shape and inform professional thinking (Shaffer, 2006).

Flow - A psychology concept that describes a mental state of operation in which a person in an activity is fully immersed in a feeling of energized focus, full involvement, and success (Csikszentmihalyi, 1997).

Folksonomy – A popular, non-expert, bottom-up classification management system, developed on the basis of how authors decide they want their works to be described or catalogued (Lankshear & Knobel, 2008, p.48).
Situated learning theory – A theory of learning that describes an unintentional process that occurs through activity in an authentic context (Lave, 2010).

Multidimensional visual spatial acuity – A term used to describe acuteness or clearness of vision with 2D/3D representations or the ability to create mental maps (Prensky, 2001).

Meta-reflective thinking – The process of thinking about and understanding one's cognitive processes (Pea & Kurland, 1984).

Meta-level thinking – A feature of creative development whereby individuals, at certain junctures, step back and reflect on their development from a broader, higher level thought process (Gee, 2005).

Neuroplasticity - It is the brain's ability to construct new neural pathways through exposure to new experiences (Neuroplasticity, 2010).

Semiotic domain – Any set of practices that recruits one or more modalities (e.g., oral or written language, images, equations, symbols, sounds, gestures, graphs, artifacts, and so forth) to communicate distinctive types of messages (Gee, 2007).

Social presence – A psychological state in which virtual physical objects are experienced as actual physical objects in either sensory or non-sensory ways (Lee, 2004).

Chapter 2: Literature Review

The apparent lack of literature related to epistemic learning would suggest that its integration into the educational realm is at the innovation stage of adoption (Massy & Zemsky, 2004). Due to the nascent nature of epistemic learning, many of its conceptual and theoretical constructs are adopted from other domains. To assist in its conceptualization, literature focusing on the changing nature of today's learner, game-based learning, evolving pedagogies and next generation learning environments will be reviewed. Theoretical perspective will be provided through an examination of literature that focuses primarily on learning principles and theories relevant to learning in the digital age. A map is provided to assist in navigating the literature review (Figure 1).

The Evolved Learner

The volume and complexity of current digital technologies and media have placed social, psychological, and cognitive demands on today's learners unseen by previous generations (Johnson, 2006). The many complex systems challenging today's learners cajole them to think and learn differently – in effect, creating evolved learners. Newer fields of research including neuroplasticity, epistemological beliefs, and cognitive development related to learning in the digital age and game-based learning are lending support to

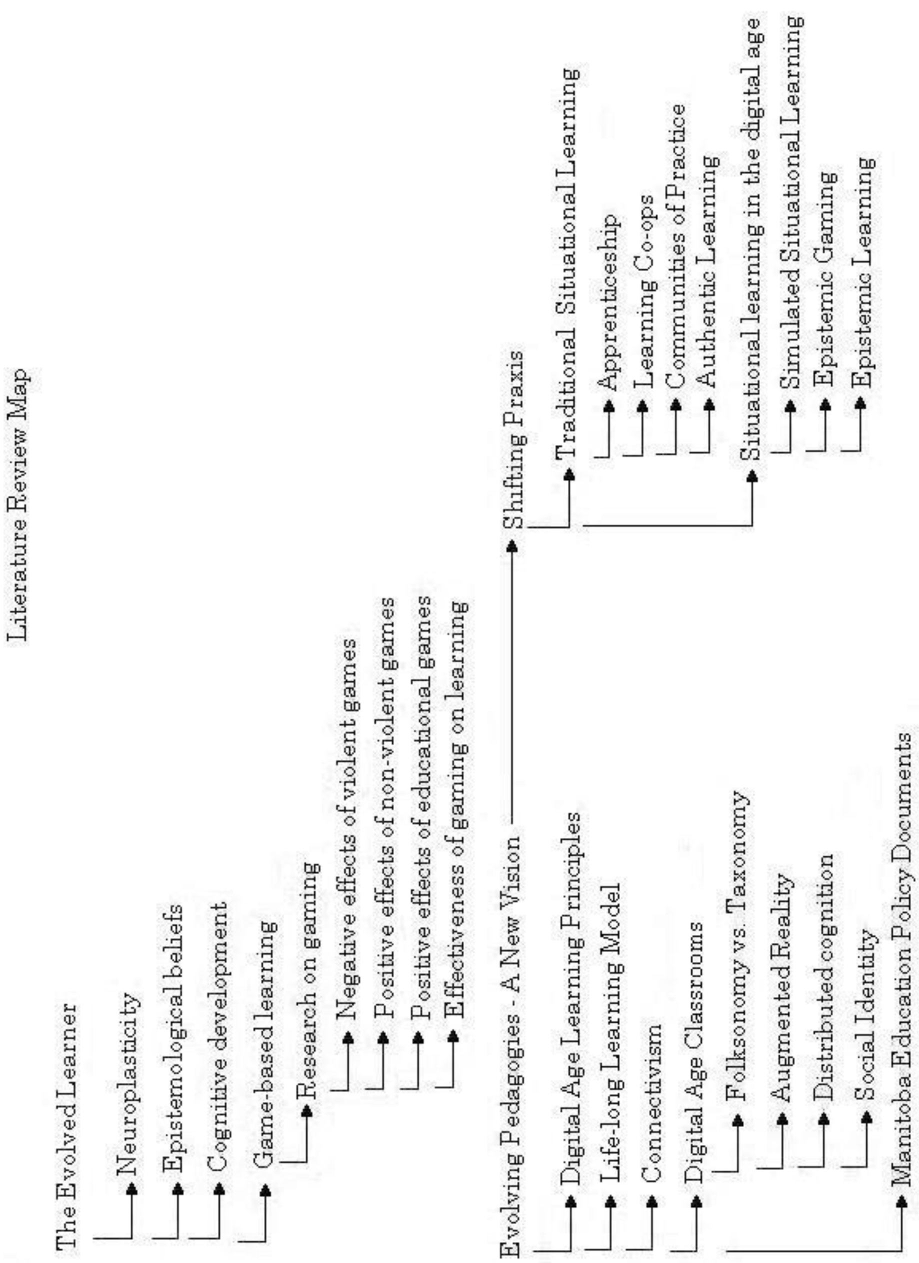

Figure 1. Literature review map.

the argument that digital age learners are evolved learners.

Neuroplasticity

Research in neurobiology has shown that the brain constantly reorganizes itself through various kinds of stimulation via a phenomenon known as neuroplasticity. Neuroplasticity refers to the potential that the brain has to reorganize in structure and function as it responds to varying experiences (Neuroplasticity, 2010). Neural pathways are created as learners focus and practice new skills or try to overcome an obstacle.

Neuroscientist Dr. Bruce Perry (2002) and neurophysiologist Dr. Alvaro Pascual-Leone (Begley, 2007) suggest that for some brain areas, such as the cortex, significant plasticity remains throughout life such that experiences can continue to alter neurophysiological organization and function. Learned behaviors become habit of the mind when neural pathways become well established (Kraljevic, 2011).

Exposure and interactions with pop culture's digital technologies and/or mediums such as video games, Internet, smart phones, mobile devices, television and movies have placed an exigency on digital age learners to flex their thinking capacities. Small and Vorgan (2008) assert that daily exposure to high technologies is responsible for stimulating brain cell alteration and neurotransmitter release such that new neural pathways are strengthened and old ones weakened. Neural development in today's learners prepares them to be both persistent and adaptable in their thinking and learning and to function in twitch-speed environments (Prensky, 2001).

Experiences with today's tools of popular culture and the socialization within have contributed and will continue to contribute significantly to enhancing neuroplasticity in digital age learners (Ibbitson & Irvine, 2005). Some would argue that the neurological development today's learners are experiencing has contributed to greater intelligence and that the changes we are seeing in children represent a transformation in human intelligence involving a more immediate, visual and three-dimensional form of thought (Healy, 1991; Johnson, 2006).

Healy (1991) pragmatically asserts that technologies can be detrimental to neuroplasticity in young minds when neural substrates for reasoning are jeopardized as a result of children not receiving proper physical, intellectual and emotional nurturance. Chirico (1998) contends that neuroplasticity can be adversely affected if stimulation is presented at an inauspicious time or in an inappropriate manner. Neuroplasticity that occurs to promote the strengthening of undesirable behaviors (i.e., addiction to gambling or drugs) or is developmentally inappropriate (i.e., receiving credit for work not done) will produce less desirable effects. Once stubborn habits or disorders are neurologically well established they may prevent more positive changes from occurring (Doidge, 2007).

Epistemological Beliefs

Habermas's view of the human condition maintains that people are incapable of not learning; that is, we must learn as part of our genetic make-up (McNiff & Whitehead, 2006). According to Habermas, three areas of human interest generate knowledge: 1) work knowledge; 2) practical knowledge; and 3) emancipatory knowledge (MacIsaac, 1996). Learning within these domains can occur in formal, informal, or non-formal settings and can be educational or non-educational[4]. Emancipatory knowledge has empowered today's learner to question traditional educational ideologies and to transform their personal epistemic beliefs by taking ownership of the need to learn and its content (Longworth, 2003).

Personal epistemology is both implicit and explicit and is developed as learners make meaning of their educational experiences, in and outside of school (Hofer, 2001). Epistemic beliefs vary from individual to individual and require development from the simple perspective to a more complex perspective through diverse educational experiences (Tutty & White, 2005). Evans and Rapert (2007) assert that the developmental level of students' epistemic beliefs must be taken into consideration when conducting learner analyses. It is these beliefs about knowledge and knowing that influences students' learning and the learning processes they choose to engage in

[4] It is the opinion of this author that any learning, be it formal, informal, or non-formal can still be considered educational providing it improves the human condition. Although it is beyond the scope of this paper, consideration needs to be given to redefining the meaning of "formal education."

(Greene & Azevedo, 2007). Research has shown that personal epistemology can impact learning and improve academic self-efficacy (Bendixen & Hartley, 2003).

Downes (2006) challenges the progression from one type of epistemic belief to a better, more sophisticated epistemic belief. He questions whether one epistemic belief is an improvement over another belief and whether the migration from one type of epistemic belief to another represents development. He opines that public schools engage in a form of indoctrination where epistemic belief sets are dictated rather than naturally developed.

Cognitive Development

Learners' cognitive powers are routinely extended through the use of the Internet to retrieve incredible quantities of information and in networking with others, by playing video games or engaging with interactive simulations that allow players to learn abstract concepts through physical representations, and/or while using devices such as external hard drives and jump drives to store and access information on demand. Johnson (2006) argues that complex environments such as the Internet and video games have the potential to enhance cognitive development as they tend to place higher cognitive demands on the participant – a phenomenon he refers to as the Flynn Effect[5]. Learning in the digital age is frequently characterized by the use of technology to access cognitive powers beyond one's innate abilities (Prenksy, 2009). By recruiting these cognitive powers, today's learners are able to use the technologies to do things that neither they nor the technology can do alone (Shaffer, 2008).

Brown (2000) believes that technologies have contributed to a dimensional shift in cognitive development relative to four pillars: literacy, reasoning, learning and action. Literacy in the digital age involves more than just understanding texts and images. It involves comprehension of multiple texts, communicating with numerous multimedia formats, and utilizing experience and triangulation to improve judgment skills essential to information navigation. In the digital age, literacy extends to include the ability to decode and interpret a myriad of semiotic domains replete with multiple representations, including oral and written language, images, equations, symbols, sounds, gestures, and artifacts (Gee, 2004; Prensky, 2006). Today's student faces greater cognitive challenges than earlier generations of learners as their intellectual development is contingent on the successful integration of multiple literacies.

[5] The Flynn Effect: The complexity of an individual's environment is defined by its stimulus and demand characteristics. The more diverse the stimuli, the greater the number of decisions required, the greater the number of considerations to be taken into account in making these decisions, and the more ill-defined and apparently contradictory the contingencies, the more complex the environment. To the degree that such an environment rewards cognitive effort, individuals should be motivated to develop their intellectual capacities and to generalize the resulting cognitive process to other situations. (Johnson, 2006, p.146)

Today's learners rely less on abstract reasoning and more on reasoning through bricolage and judgment where existing objects are transformed into something new. Examples of bricolage include mashing and modding. Mashing and modding encourage digital learners to extend their limitation of thought by creating knowledge rather than receiving it (Prensky, 2003). This alternative approach to reasoning is better suited to the digital age learner who is more readily equipped to deal with the concrete as opposed to the abstract (Brown, 2000).

Typically, cognitive growth in adolescents involves a transition from thinking concretely to thinking systematically about logical relationships within a problem (Bastable & Dart, 2007). Brown (2000, p. 72) asserts that learners make the transition through engagement in learning that "is situated in action, is both a social and a cognitive experience, is concrete in nature and includes judgment and exploration." Sword and Leggott (2007) credit wikis, chat rooms, and blogs for inspiring students to create collective knowledge. They stress that teaching in the future requires the harnessing of the collaborative impulses that already exists in digital culture. Today's students attach considerable value to being networked and constructing their knowledge socially. It is the tools of today's digital culture that assist students in displaying their creativity and demonstrating their thinking skills and problem solving abilities (Brown, 2006; Gee, 2008; Harris, 2008; Klopfer et al., 2003).

The Alliance for Children (Cordes & Miller, 2000) report on the hazards of computers in childhood identifies risks to intellectual development including lack of creativity, loss of imagination, impaired language and literacy skills, poor concentration, deficiencies in attention, plagiarism and distraction from meaning. Critics of the impact of technology on cognitive growth assert that digital technologies fail to exercise learners' intellectual faculties as knowledge and skill scores have not increased (Bauerlein, 2008) nor have technologies advanced understanding (Stoll, 1999). Cognitive development is influenced by many factors including technology. While it may serve to help some it can also fail others. Video gaming is one example of a technological innovation that can positively and negatively affect learners.

This section of the literature review provides perspective on the evolving learner, specifically with respect to neuroplasticity, epistemological beliefs, and cognitive development. Existing literature argues convincingly that learners' minds are developing differently because of their exposure and interactions with the cultural tools of the digital age. Although the literature suggests that learners have made considerable gains, the following question still remains: What sacrifices are students making in becoming evolved learners?

Game-based Learning

The Gaming Debate

Research on video gaming[6] supports the assertion that playing digital games does have psychological, behavioral, and physiological effects on participants (Anderson, 2004; Bartlett et al., 2009; Ferguson, 2007). Lee and Peng's (2004) meta-analysis of almost thirty years of computer games studies revealed that existing research focused on four areas: (1) the negative effects of violent entertainment games; (2) the positive effects of non-violent entertainment games; (3) the positive effects of educational games; and (4) the effectiveness of gaming on learning. The authors found little evidence that violent games generate positive outcomes (Sherry; Bushman, Baumeister, & Stack; Gunter as cited by Lee & Peng, 2004) and insufficient research that demonstrates the negative effects of educational games. Gaming that improves learning can be considered to have educative value as it can serve as a valuable resource in establishing methods of teaching, learning and curriculum (Egan, 2008; Foreman, 2004; Lankshear & Knobel, 2008; Rappa, Yip & Baey, 2009).

Video games have been instrumental in redefining learning for students as they are highly interactive, allow for the exploration of alternate identities without risk, and represent a new approach to learning (Shaffer et al., 2009). The 2012 Horizon Report (Johnson, Adams, & Cummins, 2012)

[6] The term gaming will be used throughout this chapter when referring to video and/or computer gaming.

identifies game-based learning and gestured base learning (i.e., Wii or Xbox Kinect) as emerging technologies that accommodate learners who are accustomed to touching, tapping, swiping, jumping, and moving as they interact with information.

In opposition, Healy (1991) asserts that the youth of today are blocked from the experience of meaningful learning by the fast-paced lifestyles and a heavy diet of visual immediacy that digital technologies proffer. Oppenheimer (2003) stresses that learning is sensory and that technology struggles to create real-life experiences – the simulated experience does not compare to tactile reality. Squire (2005) opines that bringing educational games into the classroom can contribute to motivational problems, compromise learning effectiveness with game complexity and reduce engagement as the game experience becomes compulsory.

The Kaiser Report on Media (Rideout, Foehr, & Roberts, 2010) maintains that excessive media use including video gaming can affect academic performance. Video games have also been cited for contributing to physical injury and other health problems (i.e., obesity or addiction) (Gentile et al., 2011), delayed development (Grifffths, Davies, & Chappell, 2004), and encouraging anti-social behavior (i.e., isolation and/or aggression) (Anderson et al., 2008). Video gaming can be an invaluable tool in supporting learning if used judiciously and not as a panacea to all the educational woes (Harris, 2008).

Negative effects of violent entertainment games. The negative effects of violent games have been a principal concern of many empirical game studies. The appropriateness of games with violent content comes into question because of the negative effects these games produce on a gamer's psychological, behavioral and/or physiological states (Bartlett & Rodeheffer, 2008).

Lee and Peng's (2004) meta-analysis of existing research on the effects of gaming divulged that the playing of violent video games had both positive and negative effects. Their meta-analysis disclosed that the negative effects of violent gaming included anxiety, aggressive thoughts and aggressive behaviors, addiction, poor school performance, gender stereotyping, and health problems.

Access to aggressive thoughts increased when players were required to react to aggressive words (Anderson & Dill as cited by Lee & Peng, 2004), assumed roles as active participants as opposed to passive observers (Calvert & Tan as cited by Lee & Peng, 2004) or as they were continuously exposed to violent games (Gentile et al., 2004). Repeated exposure to experiences that promote aggressive tendencies results in well-established neural pathways for aggression. Neuroplasticity of this nature is incongruous to what is considered socially acceptable (Gentile & Gentile, 2008).

Studies have revealed that boys are more dependent on games than girls (Griffith & Hunt; Tejeiro as cited by Lee & Peng, 2004). Boys with a high preference for violent games showed significantly less pro-social behavior (Bushman & Anderson, 2002) and were more likely to engage in aggressive or delinquent behavior (Anderson & Dill as cited by Lee & Peng, 2004). The research by Gentile and colleagues (2011) on pathological gaming supports that excessive playing can result in depression, anxiety, and social phobias. Addiction to gaming has also been linked to deterioration in academic performance (Gentile, 2011; Walsh; Roe & Muijs as cited by Lee & Peng, 2004; Weis & Cerankosky, 2010). Young males are the demographic most negatively impacted by violent video games as they spend considerably more time playing (Rideout, Foehr, & Roberts, 2010).

Gender stereotyping in video games has been found to impact the self-image of young girls and influence the expectations of and attitudes that young men have towards females (Cesarone as cited by Lee & Peng, 2004). Games that promote female gender stereotypes represent yet another media form that serves to undermine the healthy development of young girls.

The meta-analysis by Lee and Peng revealed mixed results. This suggests that playing violent video games may have negative effects but not as pronounced as people might imagine. The catharsis theory[7] has been applied in reasoning that violent games can be beneficial as they provide a safe outlet to exercise violence (Lee & Peng, 2004; Peng, 2004). Those who

[7] The catharsis theory implies that the execution of an aggressive action under certain conditions diminishes the aggressive drive and therefore reduces the likelihood of further aggressive actions. The crucial point in catharsis theory is that the observed aggressive action does not necessarily need to be executed in reality.

disagree with the findings of research on violent gaming deem the results inconclusive because of the lack of a measurement of long-term effects and the few observations of real aggression rather than simulated or pretended aggression (Gunter as cited by Lee & Peng, 2004). The inclusion of violent video games into an educational setting would be dubious and problematic (Bartlett & Rodeheffer, 2008) and is thus considered inappropriate for educational settings.

Positive effects of non-violent entertainment games. Shaffer et al. (2004) argue that to understand the future of learning, educators will need to look beyond schools to the emerging arena of video games. Existing research on gaming maintains that playing non-violent entertainment games can have positive effects on sociability, academic performance and cognitive development.

Benefits of non-violent gaming included social skill development through participation in environments that promote interaction and relationships (Steinkeuler & William, 2006), regular contact with their friends (Colwell, Grady, & Rhaiti as cited by Lee & Peng, 2004), and higher scores on measurements of family closeness and attachment to school (Durkin & Barber as cited by Lee & Peng, 2004; McCoy, 2009). Learning environments built around social skill development are believed to more closely approximate the experiences students will have in real-world situations (Gee, 2008; Shaffer, 2008).

The findings for the effects of playing video games on academic performance are mixed. For non-violent entertainment games, a positive relationship was found between time spent playing games and a child's intelligence and/or GPA (van Schie & Wiegman; Durkin & Barber as cited by Lee & Peng, 2004). Chuang and Chen's study (2009) on the effects of video game-based learning found that gaming helped middle years students improve their fact/recall processes and problem-solving skills.

Gaming has aided in cognitive development by providing students with skills in reading, mathematics and problem-solving (Ministry of Community Development and Sports and Media Awareness Network Canada, n.d.). Stowbridge (as cited by Lee & Peng, 2004) asserts that gaming provides children with strategies for learning-to-learn, teaches them how to process multimedia information, and encourages them to think nonlinearly. Ancillary skills learned through the acquisition of the previous skill sets include abilities in inductive discovery and problem-solving through trial-and-error (Greenfield as cited by Lee & Peng, 2004), eye-hand coordination and spatial visualization (Pepin & Dorval as cited by Lee & Peng, 2004), visual attention (Green & Bavelier as cited by Bartlett and Rodeheffer, 2008), rapid information processing, and the ability to think about a number of things at the same time (Trachtman as cited by Lee & Peng, 2004).

Bartlett and Rodeheffer's (2008) meta-analysis of fifty-eight studies (25 correlational and 33 experimental) was conducted to establish the following:

(1) the relationship between video game playing and short-term cognitive performance; (2) the increase in specific cognitive performance variables; and (3) the age group with the most significant improvement in cognitive performance. Their examination of correlational studies[8] attempted to determine if gaming influenced short-term cognitive performance and if specific cognitive variables were related to video game playing. Positive effect size estimates suggested that video gaming was related to increased cognitive performance.

Bartlett and Rodeheffer's meta-analysis of correlational studies revealed that video game playing enhanced cognitive performance (effect size $r = .19$), significantly impacted specific cognitive variables (attention effect size $r = .34$; spatial ability effect size $r = .15$; skill acquisition effect size $r = .52$; problem solving effect size $r = .69$; reaction time effect size $r = .15$; eye-hand coordination effect size $r = .15$; and intelligence effect size $r = .14$), significantly impacted overall general cognitive abilities (effect size $r = .15$) and that video game playing benefited all ages ranges, especially the 17 and under group (<17 effect size $r = .28$). Positive correlations were demonstrated between gaming and short-term cognitive performance and between gaming and an increase in specific cognitive variables. No causal connection was inferred as the studies they analyzed were correlational.

[8] Studies were coded as correlational if they reported correlational coefficients.

Bartlett and Rodeheffer's (2008) meta-analysis of experimental studies[9] also revealed that video game playing enhanced cognitive performance (effect size r = .15), significantly impacted specific cognitive variables (attention effect size r = .53; spatial ability effect size r = .28; skill acquisition effect size r = .14; tracking effect size r = .52; reaction time effect size r = .32; eye-hand coordination effect size r = .31), significantly impacted overall general cognitive abilities (effect size r = .18) and that video game playing mostly benefited those of college age and the elderly, but not young children (<17 effect size r = .02). The recall and intelligence cognitive variables were negatively related to video game playing (recall effect size = -.15 and intelligence effect size = -.17). For the experimental studies meta-analysis, the authors concluded that there was a causal short-term relationship between video gaming and cognitive performance.

Bartlett and Rodeheffer's (2008) research makes a strong argument for cognitive development through video gaming. Henderson, Klemes, and Eshart's study (as cited by Lee & Peng, 2004) showed that the mere playing of computer games without intentional instructions for the purpose of learning concepts and content still improved thinking skills and strategies. Proponents of gaming look beyond the entertainment value of such games in assessing the complexity of the game to find embedded characteristics that

[9] Studies were coded as experimental based on the statistics used to calculate effect size estimates.

promote learning (Gee, 2005; Prenksy, 2006; Shaffer, 2007; Wilen-Daugenti, 2007).

Some of the arguments against playing violent games also apply to playing non-violent games. These arguments include addictive behavior, drop in academic performance, reduction in physical fitness leading to a sedentary lifestyle, attitudes towards gender stereotypes, isolation leading to disassociation and physical injury (Gentile, 2011). Video games, like many other compelling activities, are inherently hurtful if the participant's social presence in the game exceeds that which they experience in real life. Social presence acquired through real-world learning experiences is not necessarily negative.

Positive effects of educational games. Gee (2005) contends that playing good educational games provides students with a sense of agency, teaches them system thinking, encourages them to explore thoroughly, think laterally, and to develop affinity groupings around common endeavors. Jenkins & Squire (2003) emphasize that well-designed educational games can motivate students to turn to textbooks for understanding rather than memorization and that it can encourage them to read and learn across a broad range of related fields.

Research supporting the positive effects of educational gaming on motivation, retention memory, spatial skills, cognitive skills and sociability are mostly in consensus (Peng, 2004). Research on motivation demonstrated that students are more motivated by simulation than conventional teaching (Randal et al. as cited by Lee & Peng, 2004) and games produced higher levels of continuing motivation amongst younger learning-disabled students (Malouf as cited by Lee & Peng, 2004). In 12 out of 14 studies, Randel et al. found that using simulations and gaming as opposed to conventional instruction resulted in greater retention over time.

Effectiveness of gaming on learning. Lee & Peng's (2004) analysis of existing literature on the effectiveness of gaming on learning revealed mixed results. In citing Randel, Morris and Wetzel's meta-analysis, they disclosed that 56% of the studies concluded that there was no difference between instructional effectiveness of games to conventional classroom instruction, 32% of the studies found differences favoring simulations or games, 7% favored simulations or games but their controls were questionable and 5% found differences favoring conventional instruction.

Some research suggests that gaming is more effective in certain subjects and less so in others with math having the greatest percentage of results favoring gaming (Lee & Peng, 2004; McFarlane, Sparrowhead & Heald, 2002). Blanchard, Stock, and Marshall's study (as cited by Lee & Peng, 2004) emphasizes the conflicting nature of some results. Their study reported that computer games and multimedia instruction had reliable and positive effects on achievement in mathematics problem solving, reading comprehension, and word study, yet no reliable effects in mathematics procedure, reading vocabulary, sounds and letters, and word reading.

Research on the positive effects of gaming on spatial skills and spatial visualization appears to be in consensus. Computer games were found to facilitate development of spatial skills in two and three-dimensional mental rotation in middle years children (McClurg & Chaille; Miller & Kapel as cited by Lee & Peng, 2004) and assist in bridging the gap in spatial skill awareness that exists between girls and boys (Surahmanyam & Greenfield; De Lisi & Wolford; Perzov & Kozminsky as cited by Lee & Peng, 2004).

Pillay's study (as cited by Lee & Peng, 2004) reported that playing digital games places demands on certain cognitive skills including: (1) proactive and recursive thinking; (2) systematic organization of information; (3) interpretation of visual information; (4) general search heuristics; and (5) means-ends analysis. The research of others conveyed that video games enhanced inductive reasoning (Camaioni, Ercolani, Perrucchinin, & Greenfiled; Honebein, Carr, & Duffy as cited by Lee & Peng, 2004), facilitated the development of complex thinking skills related to problem solving (Keller as cited by Lee & Peng, 2004), promoted strategic planning (Jenkins; Keller as cited by Lee & Peng, 2004) and assisted with self-regulated learning (Rieber; Zimmerman as cited by Lee & Peng, 2004). According to Jenkins (as cited by Lee & Peng, 2004), gaming can enable development of different learning styles due to its adaptive nature.

Peng and Lee attribute the positive learning outcomes of gaming to a number of theoretical constructs: (1) immersion effect – when players engross themselves in an activity and progressively increase their attention and concentration on a goal (Hubbard as cited by Lee & Peng, 2004); (2) theory of flow – as described earlier (Csikszentmihalyi, 1997); (3) input-output-outcome game model – a cyclical process that engages the player in repetitive play and repeated involvement in the game activity (Garris, Ahlers, & Driskell as cited by Lee & Peng, 2004); and (4) incidental learning – learning that is not purposely structured but occurs through observation, repetition, social interaction and problem solving during game playing (Kerka as cited by Lee & Peng, 2004).

Existing research supports that gaming is at least as effective as conventional classroom instruction. Current literature convincingly argues for the inclusion of gaming into the educational landscape based on its ability to enhance children's cognitive and attitudinal development. Effectiveness of gaming on learning is an area that cannot avoid persistent examination as there are numerous variables that impact the outcome. Next generation learning environments will likely be bolstered by video gaming or learning designed around the principles of video gaming (Gee, 2008; Johnson, Adams, & Cummins, 2012). Generally, those who oppose educational gaming also warn of the dangers of technology in schools (Bauerlein, 2008; Oppenheimer, 2003; Stroll, 1999).

Summary

Research on computer gaming addressed the following: (1) the negative effects of violent entertainment games; (2) the positive effects of non-violent entertainment games; (3) the positive effects of educational games; and (4) the effectiveness of gaming on learning. Gaming comes into question when it negatively affects physiological, behavioral and physiological development. Negative effects include anxiety, aggressive thoughts and behaviors, addiction, poor academic performance, gender stereotyping and health problems. Playing violent computer games contributes to the development of neural pathways that are not necessarily socially acceptable. Insufficient longitudinal studies have been conducted to confirm that violent video gaming promotes real aggression in participants. It is argued that although violent video games can have negative effects on the player, these effects are not as pronounced as one might believe. Most research does support the position that violent gaming is inappropriate to an educational setting.

Theorists who have studied gaming argue for its inclusion in education as gaming represents an alternative approach to learning that is more consistent with the way today's learners think and learn. Research has shown that appropriate video gaming is as instructionally effective as conventional instruction. Non-violent and educational games have benefited learners with social development, academic performance and cognitive development. Research on cognitive benefits concluded that there is both a correlational and causal relationship between video gaming and short-term cognitive development. Any gaming is inherently hurtful once it compromises a person's social presence.

Evolving Pedagogies – A New Vision

In response to the evolution of today's learners, researchers have given considerably more thought to the theories and principles that inform, guide, and influence teaching philosophies and practices. While some principles are well established and are either being revisited or adapted to the technological age, others are the brain-children of theorists and practitioners who have a futuristic vision of learning. The literature dedicated to evolving pedagogies ranges from encompassing principles like those outlined by Gee (2007) (see Appendix A) or Sword and Leggott (2007) (see Appendix C) to the holistic ideology of lifelong learning as discussed by Longworth (2003) to specific theories such as *flow state* as proposed by Csikszentmihalyi (1997) or the *connectivism* theory as proposed by Siemens (2004). The critiquing of emerging pedagogies is still at the stage where comparisons and references are made to the general and more established ideas and philosophies.

Digital Age Learning Principles

Shaffer (2008), Gee (2007), and Sword and Leggott (2007) acknowledge that the focus of education in the age of science and technology should be to provide young people with critical skills in creative thinking, collaboration and problem solving, and to prepare them to solve real-world like problems similar to those that professionals encounter. The advocates of educational gaming believe that learners are already acquiring some of these skills through video gaming (Aurilio, 2010; Ibbitson & Irvine, 2005; Prensky & Berry, 2001).

Gee believes that the theories of learning embedded in today's good video games are a better fit with today's modern high-tech world than the theories that are applied in many school settings today. Through an inspection of video gaming, Gee has proposed thirty-six principles of digital learning that constitute a framework that, if applied to teaching, could create environments that share the similar learning principles as found in the good video games.[10] Of the thirty-six principles, Gee (2005) focuses on sixteen he believes are integral to making learning in and out of schools seem more game-like (p.4-11):

1. Learning the involves exploration of identity;
2. Learning that involves interaction with the game and with others;
3. Learning that adapts to the level of the player;
4. Learning that allows for risk taking without consequences;
5. Learning that adapts to the level of the player;
6. Learning that promotes agency;
7. Learning built on well-ordered problems;
8. Learning that allows for challenge and consolidation;
9. Learning that is just-in-time and on-demand;
10. Learning that provides situated meaning to words in multiple formats (e.g., actions, images, dialogues);
11. Learning that is pleasantly frustrating;
12. Learning that encourages system thinking (i.e., relationships between objects);

[10] For a comprehensive list of Gee's digital learning principles see Appendix A.

13. Learning that encourages participants to explore, think laterally, and then rethink goals;
14. Learning through smart tools and distributed knowledge;
15. Learning that utilizes cross-functional teams, and
16. Learning that promotes performance before competence.

Many of Gee's learning principles are derived from existing theories but others are very specific to learning influenced by technology and ideologies that define learning in the future.

Sword and Leggott's (2007, ¶ 19) seven principles for educating the next generation outline the creation of learning environments for individuals who possess distinctive proficiencies informed by intensive use of technologies. In such environments, learners take greater responsibility for their own learning, cultivate multiple intelligences (individually and collaboratively) for the purpose of creating and producing knowledge, and develop resilience in the face of change. Learning environments, such as those described by Gee, Sword and Leggott, tend to be highly engaging as they match high skills with deep involvement.

The Lifelong Learning Model

The shift from a mass education and training paradigm to a lifelong learning paradigm has been influenced by many factors including globalization, technology and economy (Friedman, 2007). Longworth (2003) discusses at length a shift in learning where schools distance themselves from the 20th century model of education and training to adopting a LLLM that will prepare learners for today's global market place. The LLLM is predicated on learners taking ownership of their learning, learning as life-based for employment and fulfillment, learning as pervasive, and teachers as managers of resources and expertise rather than purveyors of information and knowledge.

Today's learner no longer experiences learning exclusively in formal settings. Medel-Añonuevo, Ohsako, and Mauch (2001, p. 2) describe lifelong learning as learning that involves "formal, non-formal, and informal patterns of learning throughout the life cycle of an individual for the conscious and continuous enhancement of the quality of life."[11] Lifelong learning embraces all three patterns of learning and is viewed as a part of life itself, applicable to all aspects of one's life and has as its primary focus the development of skills in learning-to-learn (Collins, 2009).

Learners who acquire lifelong learning skills distinguish themselves from their predecessors not by the quantity of learning they achieve but rather by the quality of their education. A defining characteristic of lifelong learners is their ability to adapt their thinking, their behavior and their mindset to cope with the changing world (Longworth, 2003). Such skills become invaluable in a world where 60% of trades and jobs to be performed in the next two decades are not yet known (Medel-Añonuevo, Ohsako & Mauch, 2001).

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[11] Taken from Coomb's Framework (Grill, 2002): 1) Formal Learning – learning that is socially organized, goal-directed and certified by a diploma or degree and conducted in schools, colleges and universities; 2) Non-formal education – learning that is socially organized and goal-directed but is not certified by formal education credentials; and 3) Informal Education – serendipitous or self-directed learning resulting from daily experience.

Donnelly (2004) argues that rather than preparing students to be independent and autonomous thinkers, adopting a lifelong learning approach has resulted in students leaving school with low levels of literacy and numeracy and incapable of working independently. While lifelong learning is process-oriented, those who support product-oriented initiatives (e.g., the No Child Left Behind Act) would argue that the purpose of education is student outcomes and that success is measured by high-stake exams (Kymes, 2004). The 2010 Pan-Canadian Assessment Program (PCAP) (Council of Ministers of Education, Canada, 2010) reaffirms that large-scale assessment projects offer innovative and contemporary direction on education policy, curriculum and classroom practice. Policy decision based on large-scale assessment leading to improvement in learning is desired but reckless when decisions lead to marginal improvement, stagnation, or a decline in learning, such as was the case with Manitoba.[12]

Connectivism

Siemens (2004) articulates a learning theory for the digital age he refers to as connectivism. This theory states, "learning can reside outside ourselves, is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing" (p. 4). This theory underlines the importance of non-traditional approaches to learning. Winn (as cited by Prensky, 2001b, p.

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[12] In the 2007 PCAP report, Manitoba ranked 5th in math, 6th in reading, and 8th in science. In the 2010 PCAP report, Manitoba's ranking dropped to 9th in math, reading and science.

3) elaborates, "linear thought processes that dominate educational systems now can actually retard learning for brains developed through game and web-surfing processes on the computer."

Some of the learning theories in play today were conceived at a time when technology was not ubiquitous and thus, failed to address how technology impacts learning. Today, learning theories that address the impact of technology on learning are evolving to enhance previous theories or outright replace them. Sontag (2009) proposes a learning theory for digital age learners entitled social- and cognitive- connectedness schemata or SCCS[13] that augments the theory proposed by Siemens. Concern arises when the technology outpaces learning theory.

The Digital Age Classroom

Folksonomy vs. taxonomy. Digital-age learners have unique needs that cannot be met by traditional pre-digital learning environments; thus, it is necessary for the educational establishment to move forward (Ibbitson & Irvine, 2005). Lankshear and Knobel (2008) discuss a shift in learning environments from a centralized, official, expert-based or top-down classification management system (i.e., taxonomy) to a non-expert, bottom-up classification management system (i.e., folksonomy). Folksonomy is difficult to achieve because the very nature of the educational structure is

[13] SCCS learning theory focuses on the formation of schemata in the process of learning. Schemata are the existing structures of knowledge and understanding upon which new knowledge is built. The social-connectedness schema governs and is structured by the ability and desire to connect socially with others. The cognitive-connectedness schema structures a student's ability and desire to know how what they are learning connects to a larger picture (Sontag, 2009).

based on taxonomy. That is, governments dictate curriculum, administrators determine the courses to be taught, and teachers decide how to teach the materials in their courses. Some progress has been made in the departmental levels of education as course frameworks are beginning to replace curriculums and teachers and students have more freedom in the activities that will define the learning experience.

Augmented reality. Research by Klopfer et al. (2003) describes collaborative learning environments built on augmented reality role playing whereby students have the opportunity to engage in a virtual practicum. Augmented realities are not virtual realities but rather a virtual overlay of data and experiences onto a real world context. Such environments are powerful when the limitations of budget, space and/or resources do not allow for a complete real-world experience. Augmented reality encourages informal learning by moving learning out of the classroom and into personal spaces (EDUCAUSE Learning Initiative, 2005). Augmented reality can only be achieved with the necessary infrastructure.

Distributed cognition. Gresser's (2005) research concluded that distributed cognition is necessary to learning as the contributions of individual members help to further the understanding in a larger group. Learning defined by affinity grouping allows people with the same endeavor or interests to not only engage in sharing their knowledge but also to create knowledge. Communities of practice have used distributed cognition to allow members to learn topics of interest quickly and effectively (Monaghan & Columbaro, 2009). Core knowledge can also be distributed among a set of real people and their smart virtual characters and/or smart tools to facilitate understanding (Gee, 2005).

Social identity. Gee (2008, p.23) offers perspective on the importance of social identity to learning: "…good learning requires participation – however vicarious – in some social group that helps learners understand and make sense of their experiences, for achieving goals and solving problems". Prensky (2008) argues that learning in the 21st century will be about creation and innovation and the sharing of one's work in a highly connected world.

Manitoba Education Policy Documents

The Manitoba Education resource documents, *Literacy with ICT Across the Curriculum: A Developmental Continuum* and the *Manitoba Curriculum Framework of Outcomes, Senior Years ICT, and Senior 2 (20S), Senior 3 (30S), and Senior 4 (40S) Computer Science* provide philosophical and pedagogical perspectives regarding education involving digital technologies in Manitoba (Manitoba Education, Citizen and Youth, 2004, 2006, 2007). These documents effectively address the changing nature of today's learner through articulation of philosophies and outcomes that are more relevant to learning today and in the future. The following statements of general outcomes reinforce the need for students to develop lifelong learning skills:

- Students are curious, active learners

- Students become lifelong learners by gradually taking responsibility for their own learning through increased engagement in planning, developing and assessing their own learning

- Students learn through collaboration and reflection

- Students demonstrate high-level critical and creative thought through invention, discovery, design and creation of original products

- Students apply reasoned judgment in deciding whether or not to use ICT, which ICT to use, and when and how to use ICT to help meet their learning goals

- Students are empowered to solve problems, improve their personal performance, and gain critical and abstract thinking skills necessary through the use of information technology

(Manitoba Education, Citizenship, and Youth, 2004, 2006, 2007)

In acknowledging these themes, the Manitoba Education documents recognize that current learners have a different mindset and that learning for these individuals encompasses the many literacies and skills that will allow them to respond and adapt to the evolving world around them.

The new frontier in education presents itself as being distant from earlier models of education as it requires educators to place greater emphasis on new technologies, new teaching strategies and new assessment practices (The Western and Northern Canadian Protocol for Collaboration in Education, 2011). The many aspects of evolving pedagogies discussed in this section are early in their adoptive stages and remain unfamiliar to many educators. Plurality of good teaching requires that education must be cautious not to adopt a “one-size fits all” philosophy (Pratt, 2002). In adopting one perspective others should not be ignored. The personal epistemologies that teachers possess regarding their learning, knowledge and teaching should serve as a guide to justify their approach to teaching. Newer pedagogies should assume their rightful place alongside many other valued and effective learning theories.

Shifting Praxis

Traditional Situational Learning

If, to the digital-age learner, knowing means doing and knowledge is primarily a set of activities and experiences, then what do knowing and knowledge mean to the teacher? The answer may rest in the willingness of teachers to create learning environments that replicate real or virtual world experiences that go beyond content, challenge undefined problems that are open to multiple interpretations, require sustained inquiry and actively engage the learner (Lombardi, 2007). Contemporary learners thrive in environments that teach them practical skills that have real world relevance – the types of skills that are learned in situational environments. The more traditional situational environments include apprenticeship, learning co-ops, communities of practice, and authentic learning. Each has its own practical value and is still engaging for today's learners. A discussion of these environments is necessary for the purpose of historical context.

Brown (2006) asserts that current educational landscapes structured on the utilization of new teaching technologies must also be bolstered with new teaching practices. Such practices have students create and learn in chorus, pull content into use immediately and are comprised of identity-forming activities. In this learning environment students engage in learning through legitimate peripheral participation whereby they undertake real work, participate in technical and social interchanges, and develop the practices, beliefs and values of a community of practice (Lave & Wenger, 1991; Shaffer, 2008). In the digital age, situational learning environments will transform to allow experiences that were once considered inaccessible or impractical in limited educational settings.

Apprenticeship. Apprenticeship is synonymous with passing on skills and knowledge to students (apprentices) through instruction by experts (masters) and has proven to be an effective instructional environment as learning is embedded in social and functional contexts (Hubbard, 2010). Workplace apprenticeship is a logical vehicle through which students can transition from school to the workplace; unfortunately, many schools struggle to provide such programming. Apprenticeship learning is still considered specialized programming and is usually made available through provincial education directorates (Manitoba Education, Entrepreneurship, Training and Trade, 2011).

Learning co-ops. Co-operative learning environments, or co-ops, involve the integration of work experience and classroom education – schools provide the technical instruction and the workplace provides the on-the-job training with pay (Algonquin College, 2010). Students involved in co-op initiatives often learn in contexts that more accurately reflect current realities in industry or business, thus acquiring the skill sets that will prepare them for the workforce.

Communities of practice. Learning through communities of practice involves working together as a group in accomplishing a task of interest or importance. These groups share information and experiences and learn from one another such that they develop personally and professionally (Lave & Wenger, 1991). Communities of practice impact education when teachers endeavor to understand students' communities and begin providing learning contexts that allow students to work together towards a common goal, solve common problems, and/or produce collaborative projects (Christiansen, 2010, p. 100).

Authentic learning. Lombardi (2007) describes authentic learning environments as settings that are typically structured on real-world applications or disciplines where skills learned closely match the real-world tasks of professionals. In these environments, problems are solved using role-playing exercises, problem-based activities, case studies, and participation in virtual communities of practice. Due to the inherently multidisciplinary nature of authentic learning environments, they are not constructed in order to teach geometry or philosophy or other content specific disciplines. Authentic learning environments provide students with the type of contextually rich environment that encourages them to reflect on the suitability of the discipline as a potential career option.

Situational Learning in the Digital Age

Simulated situational learning. Various scholars (Prensky, 2007; Shaffer et al., 2004) advocate for an educational model that uses simulated situated learning environments (SSLEs). SSLEs situate the learner in the context of a virtual environment where they are permitted to inhabit roles otherwise inaccessible to them, participate in the practices of community, experience concrete realities rather than abstract words and symbols, and develop situated understanding (Shaffer et al., 2009). SSLEs take on other forms such as the immersive multi-user virtual environment (MUVE) (Foreman, 2004). MUVEs provide situated learning environments focusing on problem-based group learning. Massively multiplayer online games (MMOGs) and massively multiplayer online role-play games (MMORPGs) are other virtual environments where students navigate dynamic, immersive environments to complete a learning task (Shaffer et al., 2004).

Epistemic games. Unlike more traditional situational learning environments that require students to participate in ancillary programs, epistemic games endeavor to bring realistic learning contexts directly to the learner through immersive role-play and games of complexity (Prensky, 2005). Epistemic games utilize epistemic framing as a fundamental design characteristic. In doing so, participants engage in gaming simulations that are based on real-world practices (Shaffer, 2006).

As Gee (2008, p. 4) observes, “games like *Full Spectrum Warrior*, *Thief*, *Riddick*, and *Tony Hawk* share knowledge and skills between virtual characters, objects, and environments and the real-world player. By the end of the game, the player has experienced a ‘career’ and has a story to tell about how his or her professional expertise grew and was put to tactical and strategic uses.” As students indulge in epistemic games, learning is facilitated through meta-level thinking, probing, mastery learning, cultural modeling, discovery and intuition. By design, epistemic games require players to function at higher levels and experience learning more deeply.

The effectiveness of epistemic gaming is attributed to its ability to trigger intrinsic motivation through learning activities that are built on challenge, feedback, fantasy and curiosity. Challenge comes from having variable difficulty level activities and multiple level goals for which attainment is tentative (Vygotsky, 1978). Immediate feedback provides the motivation to stay on task until the goal is attained or a decision is made to move forward onto something else (Csikszentmihalyi, 1997). Fantasy engagement makes epistemic learning more emotionally appealing as participants can assume roles that are otherwise inaccessible to them (Gee, 2005). Curiosity is piqued through engagement in activities that have optimal levels of informational or situational complexity and induce a state of flow

(Malone as cited by Lee & Peng, 2004). Learning that is more game-like can occur in schools if teachers are prepared to adapt their practices to include the same learning principles that are present in epistemic games (Gee, 2008).

Epistemic learning. Epistemic learning endeavors to be the real-world equivalent of epistemic gaming and applies to any profession or practice that is deemed socially acceptable. This environment offers students the opportunity to learn through the lens of a professional or practitioner by engaging them in a community of practice and through role-play acquiring the community's epistemic frame. Like epistemic gaming, epistemic learning provides students with a view of the organizing principles of practice (i.e., the epistemic frame) by teaching them to think about problems and situations in a particular way, challenging them to think like innovators, and instilling them with high personal standards and professional values (Gee, 2008). Shaffer (2008) offers perspective:

> It may be that learning to develop the epistemic frame of academic mathematicians, historians, and research scientists is an important end of the educational process. Or it may be that the epistemic frame of accountants, journalists, and foundation program officers is a more useful general way of thinking about issues numeric, civic, and scientific in body politic. Or we might decide fundamental skills for life in a global society and economy include a wide range of epistemic frames, and that different combinations of epistemic

frames matter for different students (p.47-48).

Epistemic learning shares characteristics of other situational learning environments including authentic learning or distributed authentic professionalism. It would not be inaccurate to describe epistemic learning as being thickly authentic learning; however, differences do exist. Whereas authentic learning is limited to real-world applications or disciplines, epistemic learning is much broader in scope. Epistemic learning provides students with a general learning strategy that is transferable from one learning context to the next and from one epistemic frame to another while authentic learning typically cultivates portable skills without a strategy for learning how to learn (Lombardi, 2007).

Epistemic learning differentiates itself from other learning contexts as it is theoretically structured on a digital learning system. This system consists of a digital-age appropriate theoretical construct, a performance based method of assessment and a digital intervention. Epistemic learning has, as a defining feature, the ability to create a learning environment that is very much a role-play game. If Gee's vision is for learning to be more game-like, then epistemic learning would be the template.

Summary

The emphasis of this literature review has been the relationship between learning and gaming. Strong arguments are made for educational innovation needed to accommodate the digital age learner, but the issue of how this might occur remains elusive. As well, it is acknowledged that most educators struggle with digital learning epistemologies because of how they were educated. However, little discussion is focused on how to decrease this gap between instructors and students. Gaming as entertainment has become “mainstream” for many children but whether gaming should become part of the “educational mainstream” is still a contentious issue that is worthy of continued investigation. Learning environments that are more game-like in design have the potential to be compelling for learners to participate in. Next generation learning environments may include gaming or include the design principles of good games.

Chapter 3: Research Design and Procedures

An action research methodology was selected for this study for a variety of reasons: (1) epistemic learning as an alternative educational model requires a period of adaptation; (2) epistemic frame acquisition requires a progression from the simple elements (i.e., skills and knowledge) through to the more complex elements (i.e., identity, values and epistemology); and (3) young minds require time in order to change their way of thinking. The action research paradigm was appropriate for this study as the accessing of theory from practice could not be achieved without participation from the teacher.

Kemmis's (1983) cyclical action research model (Figure 2) was adopted in the gathering and analysis of data as well as in validating evidence to justify claims on knowledge that epistemic learning as an educational model has the potential of improving instructional effectiveness in the computer science classroom. A mixed-method analysis was utilized in this study.

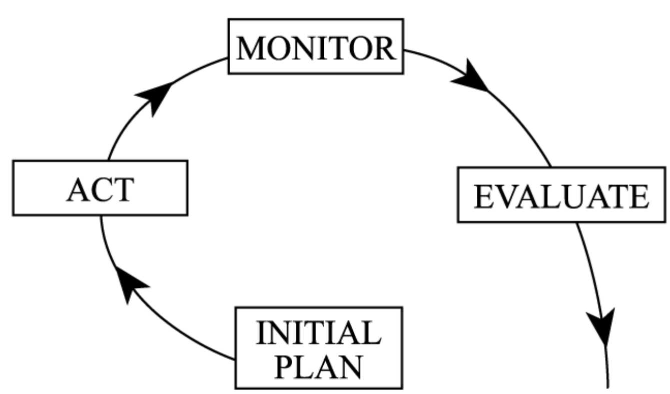

Figure 2. Kemmis's action research cycle.

The Three Stages of the Action Research Process

Past experience has provided me with the insight that traditional approaches to teaching computer science, while adequate, usually accommodated the learning needs of students who were academically strong and had little difficulty understanding abstract concepts. Epistemic learning aims to create a scenario where computer science becomes more accessible to students of different academic abilities and engages students who might not otherwise consider studying computer science. The action research approach used in this study allowed for the observation of students engaging in the epistemic learning of a computer game programmer as they emulated the behaviors and practices of members of that community. By thinking, practicing, and acting like game programmers, students had the opportunity to learn through role-play. Recent research supports that environments based on role-play and/or game-play are highly immersive, extremely engaging and effective in helping students to learn in non-traditional ways (Gee, 2005; Lankshear & Knobel, 2008; Shaffer, 2007; Sword & Leggot, 2007).

Learning the epistemic frame of a computer game programmer involved a purposeful progression through well-structured activities that resembled real-world problems. Students learned to behave and respond as game programmers through the programming of an animation, an entertainment game and an educational game using Blitz 3D (Silby, 2005).

Epistemic learning created the opportunity for students to learn computer science through computer game programming.

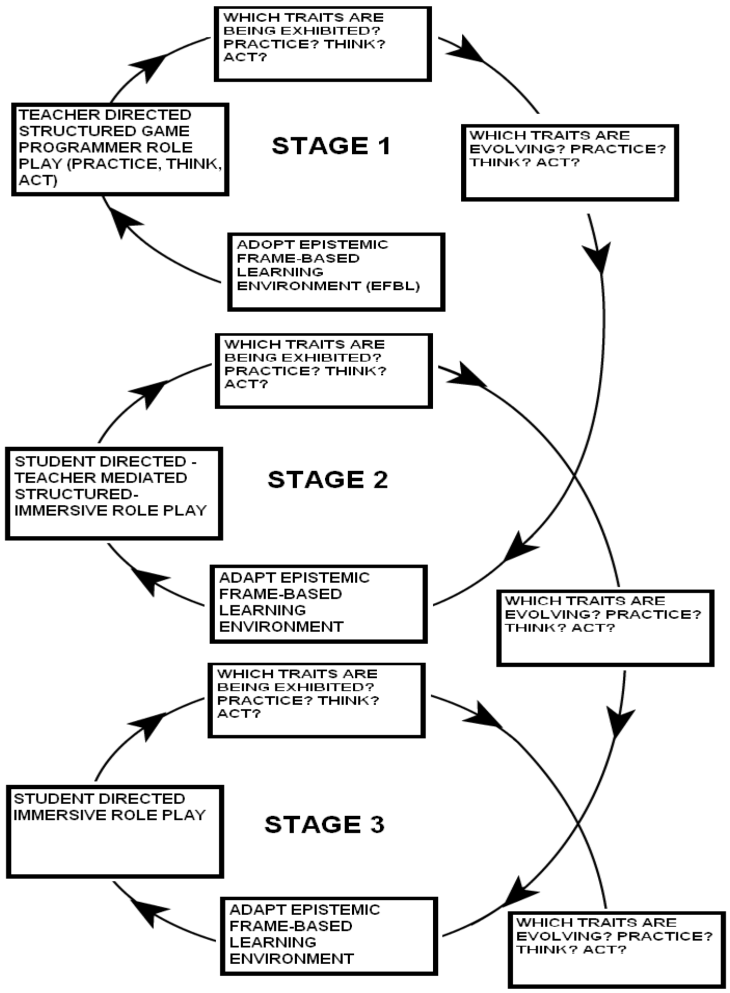

Figure 3. Three stages of the action research process.

Students were transitioned through three stages of the action research cycle in assisting them to develop the epistemic frame of a game programmer (Figure 3). The progression through the three stages included:

1. Teacher directed, structured role play - students were provided with specific objectives and some instruction.

2. Student directed, teacher mediated structured role play – students took ownership for development of their game, learning occurred through guided discovery, exploration and/or collaboration, and teacher assistance was limited to mentoring.
3. Student directed, immersive role play – students assumed complete responsibility for game design and any learning required in the development of the game.

Innovations

Blitz3D

Traditionally, computer science courses in high school have appealed to those who had a strong aptitude for mathematics or physics. To make the computer science course accessible to students, a gaming engine called Blitz3D was used to teach computer game programming. Blitz3D is a user-friendly high-level language, with English-like syntax, that provides immediate feedback, line-by-line debugging and a high-resolution 3D viewer. Blitz 3D allowed students to create three dimensional games that they could also play. All that was required to create a sophisticated program in Blitz3D was a basic knowledge of algebra, simple logic, and a grasp of some of its commands. Students were receptive to epistemic learning because of the ease of programming in Blitz 3D.

Nested Gaming

Being both a game creator and game player created an amplified environment where students turned analysis into experience (diSessa, 2000). To improve the entertainment value of their game, students played the game, decided which enhancements were to be added, learned the enhancements, reprogrammed the game, and then repeated the cycle. This environment perpetuated a learning cycle where the entertainment value of the game was dependent on the extent of programming that was learned and applied. The amplification of learning occurred as students became situated in a game within a game (i.e. programmer and player).

To further enhance the learning experience, framing education as a game created a situation where students became immersed in a game (i.e., student) within a game (i.e., game programmer) within a game (i.e, game player). The gaming metaphor applied to education has merit as progression to the next level (or grade) requires the successful completion of various tasks (i.e., learning activities). For students, epistemic learning became a single interdependent game where skill development was multi-faceted and multi-layered.

Study Participants

My research was conducted at a large suburban high school within a regularly semestered computer science class. The study candidates included students enrolled in my computer science class who had studied computer science previously and those who had no programming experience. Students taking computer science included those who enjoyed working with technology, those who have considered computer science as a possible career path, those who were earning an IT diploma[14] and those who took the course for general interest.

None of my computer science students had programming experience with Blitz3D; however, some did have experience in another programming language. To assist the students in learning Blitz3D and in developing their skills as computer game programmers, lessons and assignments were provided to allow students to learn the fundamental programming skills and to apply those skills in the creation of computer games. Lessons were prescriptive in nature while assignments required students to demonstrate their ability to apply what they had learned and to augment their learning. Initially, students worked on lessons and assignments individually but were required to collaborate as their skills improved.

From a class consisting of 20 males and 4 females, a subgroup of 5 students assented to participating in this study. Students in computer science classes were scheduled to a 75 minute class each day over a 6 day cycle. In one week, students saw me for a period of 450 minutes or 7.5 hours. Some students in the class were familiar with my approach of epistemic learning as I had taught them in other technical courses. Previous exposure

[14] The Information Technology diploma requires that students complete 8 full credits focusing on either development of technical skills with computers, production skills with computer applications, or a combination of both.

to an epistemic learning environment did not overtly influence the results as participation in epistemic learning is along a continuum.

Procedural Outline

The study of epistemic learning was conducted according to the following procedural outline:

1. The epistemic beliefs inventory (EBI) survey was distributed at the onset of the study for the purpose of collecting data regarding student epistemic beliefs. This data was essential in establishing students' perceptions on learning and their readiness to participate in epistemic learning.
2. Through discussion, students were exposed to various practices consistent with being a computer game programmer. Students were encouraged to conduct research to identify additional characteristics[15].
3. Throughout the first stage, students engaged in various lessons and assignments that created the opportunity to experience and exercise the thinking and practical skills common to computer game programmers. Skills included, but were not limited to, entering and modifying code, making a program functional, debugging for errors and creating simple programs according to a

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[15] In the absence of an industry qualified computer game programmer, I assumed the role of a game programming authority. I felt comfortable in this role as I had a decade of experience programming games and teaching game programming using a variety of languages (BASIC, Blitz3D, Visual Basic, C++, and C#).

given schema. The first assignment required students to create an animation.

4. During lessons and assignments designated for study purposes, students were observed and data was collected for actions consistent with that of a computer game programmer. Students were informed that they would be observed as this is the norm for assessment practice in all my classes. Students also reflected on their personal growth as game programmers prior to the completion of stage one.
5. The teacher-directed instructional approach of the first stage necessitated that programming concepts be taught to students and assistance provided as required. Students were encouraged to self-direct their learning to advance their programming knowledge. The following learning strategy was applied: 1) attempt to solve the problem on your own; 2) if unsuccessful, attempt to solve the problem seeking help from a friend; and 3) as a last resort, ask an expert (i.e., teacher or student with advanced skills) for further clarification. This strategy was chosen as it closely parallels how learning occurs in real-world practices and provides students with sufficient time to acquire the skills and/or knowledge (Gee, 2005, 2008; Prensky, 2007).

6. First stage assignments were analyzed for evidence of game programmer behaviors using ENA. ENA allowed for a thorough investigation of identifiable epistemic frame elements.
7. Observations and reflections were transcribed and then coded according to general categories of game programmer behaviors.
8. Observations, reflections and work samples were analyzed and interpreted in determining the adaptations to be applied in stage two.
9. In stage two, students were provided with Pea and Kurland's (1984) (Table 2) outline of programmer levels and associated observable actions and were requested to align their programming behaviors according to the outline items. Additional discussion reinforced and further enhanced the students' knowledge of a computer game programmer's behaviors.
10. Throughout the second stage, students engaged in lessons and assignments that required them to further demonstrate and/or expand their ability to think, practice and act like game programmers. The second stage was adapted to allow students to complete only the lessons they felt were necessary before attempting the assignment or to review the lessons and integrate their concepts directly into the assignment. Lessons focused on building students' programming skills through example and self-

study while assignments focused on the development and enhancement of programs.

11. In this stage, students were required to construct an entertainment game given a description of the game's objectives. Students were required to integrate multiple special effects according to the assignment parameters and of their own design. Students were required to self-direct their learning to advance their programming knowledge.
12. The student-directed, teacher-mediated instructional approach of this stage gradually shifted the responsibility for learning from the teacher to the student. Teacher assistance came in the form of well-designed guidance where students were provided prompts to stimulate thinking rather than overtly being provided the answer. For example, a student could be asked "if a cube is created using uniform scale values then what is created when non-uniform scale values are used?" In this stage, the following learning strategy was applied: 1) attempt to solve the problem on your own; 2) seek help from a classmate; 3) seek help through Internet-based programming forums, YouTube, or by accessing the Google class form; and 4) as a last resort, consult an expert.
13. Second stage assignments were analyzed for epistemic frame acquisition using ENA.

14. Students were once again observed and required to provide a reflection for the study-designated assignment.
15. Second stage observations and reflections were transcribed and then coded according to general categories of game programmer behaviors.
16. Observations, reflections, and work samples were analyzed and interpreted in determining the adaptations to be applied to stage three.
17. Adaptations made in the third stage were customized to the individual based on the game programming behaviors s/he had acquired through the first two stages.
18. Throughout the final stage, students were involved in immersive role play requiring them to rely on their own skills, intuition and initiative in creating a unique educational computer game and solving any problems that occurred. Students were required to demonstrate their abilities to think, practice and act like a game programmer by consolidating their learning, making decisions about how to move forward, justifying their decisions and taking action. Students were given greater autonomy in determining the final outcome of the educational game and how that outcome was to be achieved. Students relied on constructive feedback from the

instructor or other students in assisting them to improve and/or complete their game.

19. The final assignment was analyzed using ENA.
20. Once again, students were observed for game programmer behaviors and field notes of observable actions were kept.
21. Observations were transcribed and coded for evidence of game programmer behaviors.
22. At the end of stage three, students were interviewed to provide insight into their experiences with epistemic learning and their learning gains as computer game programmers.
23. Interview responses were transcribed and coded for evidence of game programmer behaviors and the efficacy of epistemic learning.
24. The EBI survey was again administered at the end of stage three.
25. Pre- and post-study EBI survey results were compared to determine if participation in epistemic learning affected students' epistemic beliefs.

Epistemic Beliefs Inventory (EBI)

Bendixen, Schraw, and Dunkle's (1998) EBI survey was used in this study to answer the research question: How do shifting epistemic beliefs influence epistemic learning? The data provided by the EBI questionnaire was helpful in determining the students' preparedness to participate in a higher functioning learning environment and their position on knowledge prior to and after participating in epistemic learning. EBI data is helpful to educators that are considering creating environments that require students to use higher-order thinking skills in advancing their positions on knowledge (Evans & Ravert, 2007).

The EBI survey adopted for this study identified five dimensions about knowledge and knowing, including simple knowledge (6 items), certain knowledge (5 items), omniscient knowledge (5 items), innate learning (5 items), and quick learning (4 items) (Table 1). Bendixen et al.'s version of the EBI survey was adopted for this study as it was deemed to have good reliability and factorial validity[16] and as a self-report instrument, it was uncomplicated and efficient (Greene & Azevedo, 2007).

EBI Data Collection

The EBI survey was administered by a colleague to ensure the study participants' anonymity. The survey was utilized as a pre- and post-test measure in determining if students had developed a more complex position on knowledge as a result of their involvement in an epistemic learning environment. The EBI is a Likert-type scale questionnaire consisting of twenty five questions (Appendix B). A high score for each item on the EBI represented naïve epistemic beliefs of knowledge while a low score indicated a more complex position on knowledge. The data collected from this

[16] Factorial validity is important in the context of establishing the validity of latent constructs. Latent constructs, also known as latent variables, are research abstractions that cannot be measured directly, variables such as beliefs and perceptions (Gefen, D. & Straub, D.W., 2005, p. 91).

instrument was recorded numerically and was analyzed using non-experimental descriptive analysis and inductive inquiry analysis. Descriptive analysis was conducted using mean scores and mean differences. Inductive analysis involved categorization of data according to knowledge dimensions in establishing themes, patterns and perspectives of personal epistemology. Table 1 provides a correspondence between EBI survey items and knowledge dimensions.

Table 1

*Epistemic Beliefs Inventory Survey**

Questions	Knowledge dimension
1) Most things worth knowing are not very complicated	simple
2) People should respect the opinions of authorities	omniscient
3) Really smart students learn things with less effort	innate
4) There are certain truths in life that won't ever change	certain
5) Working on a problem with no quick solution is a waste of time	quick
6) What is true today will be true tomorrow	certain
7) Society needs strong laws to work well	omniscient
8) When someone in authority tells me what to do, I usually do it	omniscient
9) Really smart students don't have to work as hard to do well	innate
10) Solutions to problems usually come quickly or not at all	quick
11) Most important ideas are pretty simple when you get down to it	simple
12) Some people are born with more ability than others	innate
13) Teachers should focus on facts instead of abstract ideas	simple
14) Basic truths exist even though we might not know what they are	certain
15) How well you do in school depends on how smart you are	innate
16) Too many theories just complicate things	simple
17) Things are simpler than most experts would have you believe	simple
18) If you don't learn something quickly, you won't ever learn it	quick
19) If two people are arguing about something, at least one of them must be wrong	certain
20) Children should never question their parents' authority	omniscient

(table continues)

21) If you don't understand a problem right away, going back over it won't help	quick
22) People should obey the law	omniscient
23) The moral rules I live by apply to everyone	certain
24) Smart people are born that way	innate
25) Most of what you learn, you learn during the first try	simple

*This tool was developed by Bendixen, Schraw & Dunkle (1998).

Epistemic Network Analysis

This study also endeavored to answer the research question: Which computer game programmer epistemic frame elements are acquired through epistemic learning? Rupp et al. (2010) identify five epistemic frame elements (SKIVE) which appear below:

- skills – the things people do within the community;
- knowledge – the understandings that people share in the community;
- identity – the ways that members of the community see themselves;
- values – the beliefs that members of the community hold, and
- epistemology – the warrants that justify actions or claims as legitimate within the community

Pea and Kurland (1984) provide a continuum of levels through which programmers progressed, from novice to expert. The levels are as follows (p. 152 -155):

1. Program user – student has the ability to use programs not coded by user;
2. Code generator – student knows the syntax and semantics of the more common commands in a programming language;
3. Program generator – student has mastery of basic commands and is beginning to think in terms of higher level units and

4. Software developer – student is ready to write programs that are complex and take full advantage of the computer's capabilities

In this study, ENA was based on the observation of specific actions[17] that corresponded to specific epistemic frame elements within programming levels (Table 2).

Table 2

Pea & Kurland's Skill Levels and Observable Actions

Level	Observable action	Epistemic element	Code
Program user	Enter **code**	Skill	S_C
	Simple code **modification**	Skill	S_M
	Execute code	Skill	S_X
	Use **quick** keys	Skill	S_Q
	Use program menus to control **program operation**	Skill	S_{PO}
	Integration with other programs	Knowledge	K_I
Code generator	Exercise **precise expression** and/or using logical code blocks	Knowledge	K_{PE}
	Write simple programs following a given **schema** and/or applying library code	Knowledge	K_S
	Learning and/or recalling **formal procedures**, variables, functions	Knowledge	K_{FP}
	Debug for errors	Knowledge	K_D
	Transfer of mental models 3D effects	Knowledge	K_M
	Exercise **situational thinking**	Identity	I_{MR}
	Interpret other people's programs	Identity	I_I
	Display **originality** in coding programs and/or extending learning beyond taught material	Identity	Io

(table continues)

[17] The observable actions have been inferred from the levels that Pea and Kurland (1984) identify and do not represent a comprehensive list. For the purpose of this research project, the observable actions selected were considered to be the most significant. As well, programmer levels were not necessarily restricted to one identifiable epistemic element.

Program generator	Exercise **adaptive thinking**	Identity	I_{ML}
	Apply **heuristics** to problem solving	Identity	I_{H}
	Skill transfer within/between programs/ languages	Identity	I_{ST}
	Exercise **persistence** in the face of difficulty	Identity	I_{P}
	Self-assessing code for the purpose of improvement or augmentation	Values	V_{SA}
	Giving **consideration** to solving coding issues through a multiple paths approach	Values	V_{CN}
	Discipline in documenting programs so others can modify it	Values	V_{D}
	Appreciation for the process of planning and designing a successful program	Values	V_{A}
	Commitment to meeting the needs of clients (i.e., completing work within deadlines, amending code according to client expectations, accepting critical feedback, etc.)	Values	V_{CT}
Software developer	Making **judgments** using quantifiable sources	Epistemology	E_{J}
	Respecting **dominant design** principles	Epistemology	E_{DD}
	Enhanced **recognition of domains** beyond programming (i.e., choosing to learn adjunct concepts critical to successful programming)	Epistemology	E_{RD}
	Collaboration in program development and design and contributing to group intelligence	Epistemology	E_{C}
	Practicing and applying efficient and effective **programming conventions**	Epistemology	E_{PC}

Epistemic frame development was contingent on participants invoking pairs of epistemic frame elements simultaneously. Epistemic frame assessment involved examining work samples for co-activation of these elements. Strength of epistemic frame acquisition was determined by the quantity of elements co-activated and the frequency of co-activation of elements - the greater the quantity and frequency of associations the more robust the epistemic frame (Shaffer et al., 2009). Svarovsky's (2009) research argues that the development of strong epistemic frames enables learners to transition from novice to expert practitioners.

ENA of Students' Work Samples

A three-tiered strategy that involved examining individual code lines, logical code blocks and the program as a single structure was applied to ENA analysis of work samples data (Figure 4). This approach was justified as programmers must demonstrate an understanding of every aspect of programming including command codes, logical structuring and program design. The three-tiered approach also mitigated for the possibility of coding redundancy. Coding redundancy occurs when an instance of SKIVE element co-activation is duplicated. It was deemed that once a participant provided evidence of mastery for specific aspects of programming it was not necessary to code for each occurrence. Episodes of self-taught or original programming were coded for each instance as it demonstrated that students were acquiring epistemic frame elements without teacher intervention. By examining work samples according to three categories, this investigator was able to determine the skills students were acquiring as they progressed from code generators to program designers to software developers.

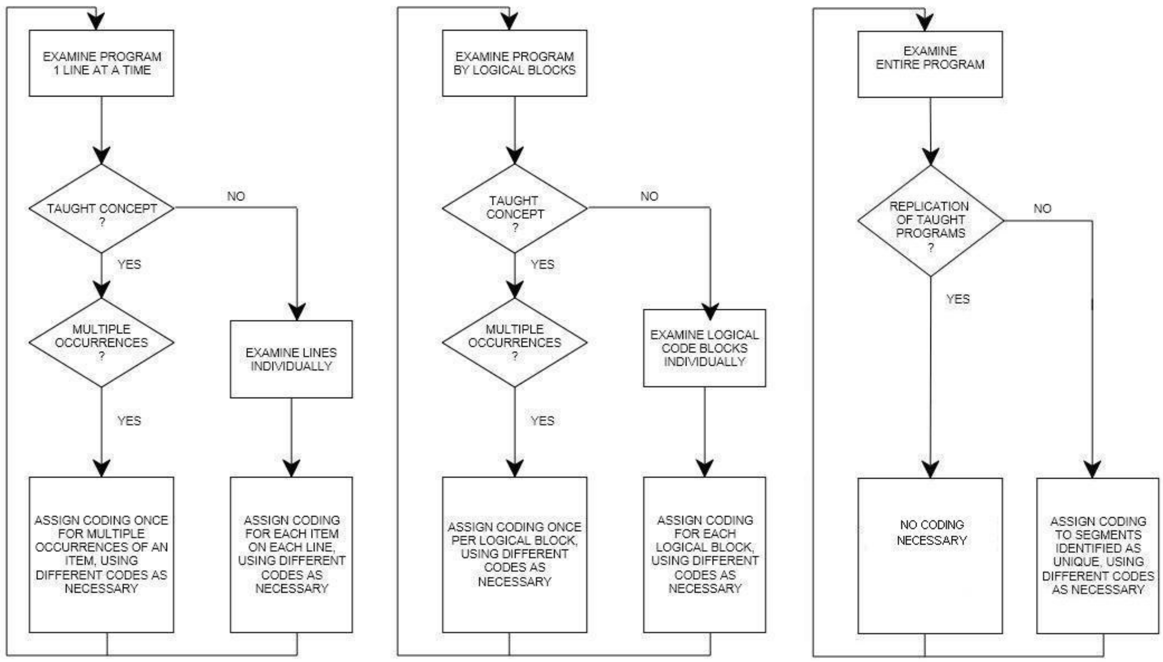

Figure 4. Three-tiered approach to ENA.

The first analysis examined individual code lines to account for recollection of taught programming constructs and/or evidence of original programming. The focus of this analysis was to determine if students were recalling taught material and/or extending their learning beyond what was taught. Application of taught programming concepts and/or commands was coded once for its use while instances of original programming concepts were coded for each new occurrence.

The second analysis examined logical blocks of code to account for the recollection of taught material vis-à-vis logical structures and/or library code and/or the creation of original logical structures. The focus of this analysis was to determine if students understood the logical organization of programs and their ability to use and/or create logical structures. Application of taught logical structures and/or library coding was coded once for its use while instances of original logical structures or library code were coded for each occurrence.

The final analysis examined the program as a single entity to determine if students were demonstrating the advanced programming aptitudes of technique and style. The focus of this analysis was to determine how epistemic frame acquisition was influencing program development and design.

ENA Data Collection

ENA involves the coding and accumulation of co-activated SKIVE elements for different assignments at distinct time intervals (Choi et al., 2010; Shaffer et al., 2009). During each action research stage, a work sample was analyzed and then coded using a SKIVE pair scheme (Table 2). For example, when the Knowledge and Identity epistemic frame elements were co-activated for a specific aspect of a work sample, the code KI was assigned. In all, three work samples were analyzed (i.e., an animation, an entertainment game, and an educational game). SKIVE code pairs where accumulated and represented in a symmetrical cumulative adjacency matrix[18].

[18]A cumulative adjacency matrix is a frequency chart that is used to record the occurrence(s) of an event. The cumulative adjacency matrix used in this study was a numerical descriptive measure to represent co-activation of epistemic frame elements.

Non-experimental descriptive analysis was used to analyze numeric data provided by ENA. Data from the cumulative adjacency matrix was interpreted using the UCINET social networking analysis program and was represented as a non-directed, single-node graph of the relationships between SKIVE pairs (Borgatti, Everett, & Freeman, 2002). A social network graphing tool was selected as it conveniently emphasized the relationship between SKIVE elements.

The resulting SKIVE graphs were depicted as a pentagon to assist with readability. The SKIVE graph consisted of individual SKIVE elements or *nodes*, an adjoining line between nodes to represent the co-activation of SKIVE pairs or *links*, and a frequency value for each SKIVE pair co-activation or *link weight.* Epistemic frame development occurred as more links were established and as the link weight increased. The work samples selected demonstrated the participants' progression through epistemic learning during each stage of the action research cycle.

Observations, Reflections and Data Collection

The purpose of observations and reflections was to identify and record events and actions by students that were consistent with the practices of a game programmer. Observations provided me with the opportunity to witness the students' learning gains while reflections permitted students to share perspective on their own growth as game programmers. ENA could not be applied effectively to observations and/or reflections because of the rigor required in its methodology. ENA proved impractical because the condition of anonymity necessitated that all students be observed and time constraints impeded persistent observation of individuals.

Observations and reflections were limited to those occasions when students were working on the assignments designated for this study. Since it proved impractical to keep observational field notes during class, it was necessary to recall and record the events at the conclusion of each class. On a daily basis, an audio journal was kept to record observational data. Students wrote their reflections to elaborate on their learning experiences on study-designated assignments. Observational notes and reflections were then transcribed to identify themes or categories consistent with the epistemic learning of a computer game programmer.

Inductive inquiry analysis was used to analyze observational and reflection data. Applying Fredericks, Blumerfeld and Paris's (2004) categories of engagement allowed for observations of learning based on cognitive, behavioral and attitudinal (i.e., think, practice, and act, respectively) development. Collecting data for observations and reflections according to broader categories of performance did not diminish the quality of data collected nor did it compromise the thoroughness of the analysis.

Approval and Access

Permission was obtained from my principal and division superintendent to conduct action research in my classroom. Informed consent was obtained from students and their parents/guardians thus providing permission for the student to participate in the study. Approval to conduct research with students with whom I had a power-over relationship was obtained from the Education/Nursing Research Ethics Board (ENREB). Accessibility was assured as I worked with only those students I taught.

Full disclosure of the study (Appendix E) intent was provided to parents/guardians and students via letter, presentation or both. The presentation to parents/guardians was conducted by a fellow colleague who assisted me with aspects of my research. As I was using an alternative approach to teaching that was considered emerging pedagogy, it was necessary to explain to parents/guardians the differences between traditional educational structures and epistemic learning. Schools and teachers have an obligation to inform parents/guardians of new or different learning arrangements as a matter of courtesy. In providing permission, parents/guardians needed to feel confident that their child's education was not being compromised.

Ethical Considerations

As I was in a position of power, every effort was made to ensure that my students were protected. I began by declaring my position of power to both parents and students at the onset of the study to build trust and avoid deception. Ensuring anonymity and confidentiality of the students was addressed using the following strategies: (1) third party recruitment was utilized; (2) the identities of the study participants were not revealed to me until the course was completed and a mark was assigned; (3) pseudonyms or numbers were used when it became necessary to report individual responses; (4) reporting of quantitative data was done in aggregate form to avoid revealing individual responses; (5) data collected was kept in a secure, locked location off campus; (6) any material used as data was only accessible to me; and (7) any material used in the study was to be destroyed one year after the completion of the study. In addition, guarantees were provided that there would be no penalties or rewards for participation in or withdrawal from the study. A summary report of the research was provided to parents shortly after the research was completed and a full report became available upon completion of the study.

Chapter 4: Results and Discussion

The analysis of the data in this study endeavored to answer the following research questions: 1) how does epistemic learning influence personal epistemic beliefs; 2) which epistemic frame qualities of a computer game programmer are achieved through epistemic learning; and 3) is learning computer science enhanced through participation in epistemic learning? The ensuing results support that students possess a readiness to participate in and are able to achieve success in a high-functioning environment such as epistemic learning.

Epistemic Beliefs Inventory Analysis

The ability to apply higher-order thinking and to reason logically typically emerges in adolescents; thus, it is important that the learning environment in which students participate is developmentally appropriate (Bastable & Dart, 2007). The EBI survey was integral to this study as it provided data that could be analyzed to determine a student's level of preparedness to participate in a higher-functioning environment.

Study participants (N = 5) completed a pre- and post-study EBI of 25 questions (Appendix B) that surveyed their attitudes towards five categories of knowledge and learning (i.e., simple, quick, certain, innate, and omniscient). Attitudinal perspectives of individual items were ranked on a Likert-scale ranging from 1 (strongly agree) to 6 (strongly disagree). Low scores signified a complex position on knowledge and learning while high scores represented a naïve position. Individual and group pre- and post-study mean scores were calculated as an indicator of epistemic beliefs. Means ranged between M = 1 (i.e., the most complex position) to M = 6 (i.e., the most naïve position). A comparative benchmark mean score (M = 3.262) was calculated using data provided by Nietfeld and Ender's (2003) research on epistemic beliefs of teachers-in-training. The comparative mean value was considered a reasonable indicator of a complex epistemic beliefs system based on Evans and Ravert's (2007) argument that an individual's position on knowledge and learning is influenced by their education.

Students' individual and group EBI scores were analyzed using the mean difference. Mean differences were compared against the benchmark to determine the attitudinal shift in epistemic beliefs as a result of participation in epistemic learning. A positive difference represented a shift towards a complex epistemic beliefs position while a negative difference supported a shift towards a naïve position. Mean differences were analyzed for practicality as a causal or correlational relationship could not be determined due to the low number of study participants.

Individual EBI - Results and Discussion

Table 3 provides a summary of each individual's pre- and post-study means and his/her corresponding mean difference. Pre-study means revealed that three participants (Students #1, #2, and #5) had scores indicative of an existing epistemic beliefs system that could be considered complex or near complex since their scores were below or near the comparative benchmark (M = 3.262). Two participants (Students #3 and #4) had pre-study scores representative of an epistemic beliefs system that was in the developmental stages as their scores were marginally higher than the benchmark.

Table 3

Individual Epistemic Beliefs Mean Scores and Mean Differences

Subject	Pre-study means (Mx)	Post-study means (My)	Mean differences (MD)
1	2.800	2.680	0.120
2	2.640	2.360	0.280
3	4.040	3.680	0.360
4	3.840	3.800	0.040
5	2.960	3.040	-0.080

The results summarized in Table 3 assisted in establishing students' receptiveness to epistemic learning. Four mean differences were reported as positive (Students #1, #2, #3 and #4) and one was reported as negative (Student #5). The positive mean differences suggest that four students benefited from epistemic learning as they experienced a shift in attitude, in varying degrees, towards a more complex personal epistemology. Even in the absence of statistical significance, a positive mean difference has practical value as it indicates that students had experienced learning gains. The magnitude of the mean difference is left to the interpretation of the instructor.

Student #3 responded most favorably towards epistemic learning as is evidenced by the magnitude of the mean difference (MD = 0.360). It would be reasonable to infer from this data that the student with the most naïve epistemic beliefs achieved the greatest learning gains due to participation in epistemic learning. The data for Student #5 (MD = -0.080) suggests that s/he reverted to a more naïve personal epistemology; however, the mean difference was too negligible to displace the student from an already complex epistemic beliefs system. The clustering of post-study mean scores towards the benchmark (M = 3.262) and the prevalence of positive mean differences suggest that students responded favorably to epistemic learning.

Group EBI - Results and Discussion

Table 4 provides a summary of the group's epistemic beliefs. An examination of group epistemic beliefs assisted in establishing the appropriateness of epistemic learning for group teaching. The data supports that the group had a pre-existing complex epistemic beliefs system and that a positive attitudinal shift occurred after participating in epistemic learning.

Table 4

Group Epistemic Beliefs Mean Score and Mean Difference

Subject	Pre-study mean (M_x)	Post-study mean (M_y)	Mean difference (MD)
Group	3.256	3.112	0.114

Effective group teaching strategies are required to ensure students progress appropriately when sorted by age and/or developmental level. The results in Table 4 support that students had made learning gains as a class and that epistemic learning was an appropriate environment for group teaching. As most conventional classrooms are currently organized according to age and grade level, environments that benefit the group are preferred.

Group EBI within Knowledge Categories - Results and Discussion

Group pre- and post-study mean scores were calculated for each knowledge category as an indicator of epistemic position. Tables 5 and 6 provide a summary of the group's pre- and post-study means and the corresponding mean difference within each knowledge category. Nietfeld and Enders's (2003) knowledge category mean scores (i.e., simple knowledge M = 3.59, innate knowledge M = 3.01, omniscient authority M = 4.59, quick learning M = 1.85 and certain knowledge M = 3.27) were used as comparative benchmarks in determining group epistemic beliefs position within knowledge categories.

Pre-study means revealed that the group's epistemic beliefs were in the developmental stages in three knowledge categories (i.e., simple, certain and omniscient) (Table 5) as these mean scores were ranked higher than the respective category comparative benchmarks. Mean scores in two knowledge categories (i.e., quick and innate) (Table 6) suggest that the group possessed a complex epistemic position in these categories as the mean scores were lower than the category comparative benchmarks. Post-study means revealed that the group's less developed knowledge categories had improved and their more developed knowledge categories had slightly regressed.

Table 5

*Epistemic Beliefs Knowledge Categories Reporting a Positive Mean Difference**

Knowledge Category	Pre-study means (Mx)	Post-study means (My)	Mean differences (MD)
Simple	3.800	3.500	0.300
Certain	3.520	3.060	0.460
Omniscient	3.920	3.840	0.080

*See Table 1 (p. 73) for a correspondence between EBI survey questions and knowledge categories

Table 6

*Epistemic Beliefs Knowledge Categories Reporting a Negative Mean Difference**

Knowledge Category	Pre-study means (M_x)	Post-study means (M_y)	Mean differences (MD)
Quick	2.250	2.350	-0.100
Innate	2.480	2.520	-0.040

* See Table 1 (p. 73) for a correspondence between EBI survey questions and knowledge categories

A positive mean difference (Table 5) for the three developing knowledge categories (i.e., simple, certain and omniscient) suggests an attitudinal shift towards a more complex perspective. The negative mean differences (Table 6) reported for the remaining knowledge categories suggest a trivial shift towards a naïve position but not enough to displace an already complex perspective in these categories. Personal epistemological growth occurs through development of individual knowledge categories. Over time, this development influences students' learning strategies and outcomes in many disciplines (Conley et al., 2004; Kienhues, Bromme, & Stahl, 2010). In this study, participation in epistemic learning contributed to the development of the three lesser-established categories (i.e., simple, certain, omniscient) and did not substantially influence the more established knowledge categories (i.e., quick and innate).

In the context of this study, the group experienced the greatest shift in attitude in the certain knowledge category. That is, the group shifted its beliefs that knowledge is concrete and absolute to knowledge being tentative and constantly evolving. The notable mean difference for the certain knowledge category suggests that epistemic learning can markedly influence the development of one category over another. Research literature supports that students with greater insights into the dynamics of knowledge typically enjoy more success in school (Evans & Ravert, 2007). Ideally, the development of all knowledge categories is preferred but a substantial development of a single category is still of great value as it signifies that students' attitudes towards knowledge and learning can be advanced.

EBI Results Summary

The results from EBI analysis support that most students already possessed a complex personal epistemology and that participation in epistemic learning further advanced their beliefs about knowledge and learning. Although there is insufficient evidence to establish a causal or correlational relationship between epistemic learning and an attitudinal shift in knowledge, data suggests that epistemic learning did influence attitudinal shifts.

It should be expected that the development of epistemic beliefs does not occur instantaneously. Personal epistemology takes considerable time to evolve and the attitudinal shifts that occurred may be reasonable given the context of learning for these participants (i.e., 70 minutes per day for 5 months). It is also reasonable to assume that the shift in students' epistemic beliefs was less pronounced because of their limited exposure and experience with epistemic learning. More longitudinal research on epistemic belief development would be beneficial in establishing a typical progression. At present, this research is sparse.

Any scenario where students' personal epistemology scores exceed those of teachers-in-training has serious implications for education. The EBI data suggests that students are capable of functioning at higher knowledge levels than they currently do and may require learning environments that are better suited to their developmental levels (Bastable & Dart, 2007).

Epistemic Network Analysis Graphs

Due to the rigors of ENA data collection, the time constraints imposed by scheduled periods, and the guarantee of anonymity, collecting ENA data while observing the entire class proved impractical. Consequently, it was deemed necessary to apply ENA only to work samples and utilize a different analysis method with observational, reflection and interview data. Given the nascent nature of ENA, it was felt that a separate discussion of ENA results was warranted.

Jordan's ENA Graphs

Jordan's ENA graphs (Figure 5) convey that epistemic frame development was quickly initiated in stage one, significantly expanded in stage two and remained constant through stage three. The strong skills-knowledge and knowledge-identity link-weights in stage one ENA suggest that Jordan emphasized these elements over others because s/he considered them integral to his/her growth as a game programmer. His/her learning gains exceeded the expectations for epistemic frame development in this stage as evidenced by the near-complete connectivity of all element nodes.

The skills-knowledge-identity (SKI) association in stage one also suggests that Jordan was developing an understanding of learning that was more closely related to how one perceives him/herself as a learner. In Jordan's situation, s/he began cultivating the praxis of a game programmer by thinking, learning and behaving like a game programmer (Brown, 2002). This is evidenced in Jordan's ability to establish most element node links in stage one independent of any instruction.

Jordan's stage two ENA results confirm that his/her perception of learning had changed and that s/he had made noticeable learning gains towards developing a computer game programmer's habits-of-mind. By stage two, Jordan was improving the robustness of his/her epistemic frame by routinely co-activating frame elements (Shaffer, 2008; Svarovsky, 2009). S/he continued to reinforce his/her epistemic frame development throughout stage three.

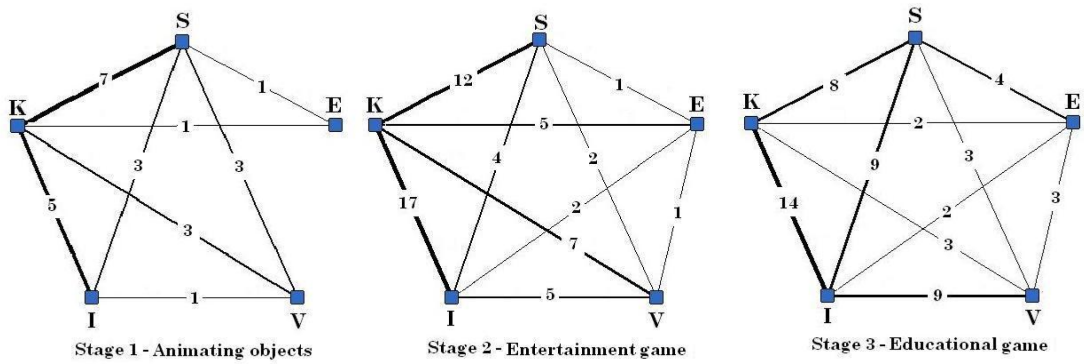

Figure 5. Jordan's epistemic network graphs.

Lorie’s ENA Graphs

Lorie’s ENA graphs (Figure 6) convey that epistemic frame development occurred steadily through stage one, expanded through stage two, and remained constant in stage three. The particularly strong skills-knowledge link-weight evidenced in stage one suggests that Lorie placed considerable value on the development and application of the fundamental skills and practices. Stage one ENA also revealed a SKI association that suggests Lorie recognized that becoming a game programmer extended beyond the acquisition of skills and knowledge. This is evidenced by Lorie’s ability to acquire frame elements not previously taught by self-directing his/her own learning. His/her learning gains were consistent with the expectations for epistemic frame development in this stage.

Stage two ENA supports that Lorie’s perception of learning had changed as his/her epistemic frame continued to emphasize existing links and expanded to include new links. Although Lorie was unsuccessful in establishing complete connectivity between element nodes, s/he made reasonable progress towards developing the epistemic frame of a computer game programmer.

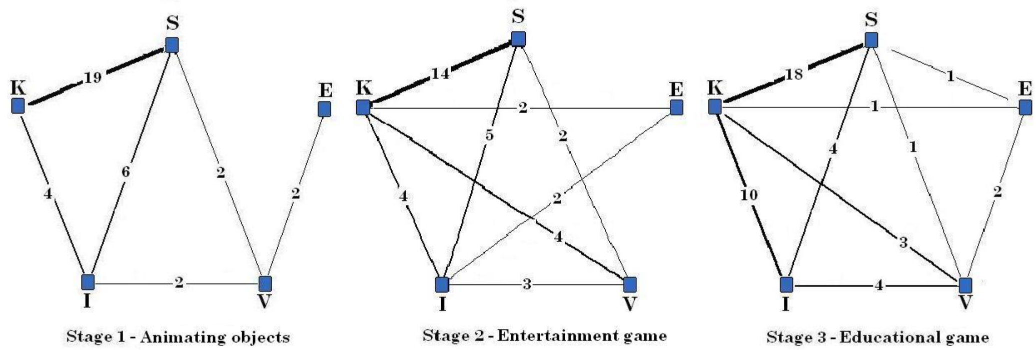

Figure 6. Lorie's epistemic network graphs.

Alex’s ENA Graphs

Alex’s ENA graphs (Figure 7) convey that epistemic frame development occurred slowly through stage one, expanded markedly through stage two, and was further enhanced in stage three. Stage one ENA revealed that his/her primary concern was meeting stage one outcomes – the acquisition of the skills and knowledge elements common to game programming. A SKI association also emerged in stage one but had little influence on Alex’s learning gains as evidenced by the weak link-weights between SKI elements. Alex’s progress was consistent with the expectation for this stage as s/he was able to establish a strong link-weight between the skills and knowledge elements.

In stage two ENA, Alex's receptivity to epistemic learning became more pronounced as s/he made appreciable learning gains in establishing and maintaining strong node connections. A stronger SKI association, an evolving Knowledge-Identity-Values (KIV) association and an increase in node links support that his/her perceptions about learning and knowledge formation had broadened to involve the interaction of multiple processes. At this stage, Alex recognized that membership into a community of practice encompassed accepting its beliefs, attitudes and ideas and acting on them in a mindful and reflective manner (Christiansen, 2010).

Learning gains through stage three continued to support Alex's epistemic frame development as evidenced by more robust SKI and KIV associations and continued node connectivity. Although complete connectivity between element nodes was not established, the link frequency and the strength of the linked nodes confirm that s/he made considerable progress towards developing the epistemic frame of a computer game programmer.

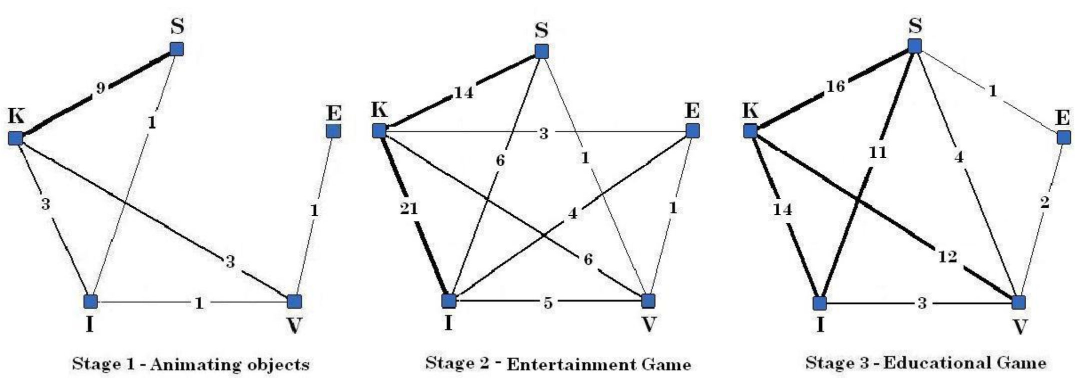

Figure 7. Alex's epistemic network graphs.

Brook's ENA Graphs

Brook's ENA graphs (Figure 8) convey that his/her epistemic frame development through three stages progressed similarly to other students. The ENA graphs support that Brook successfully established new links, maintained and/or strengthened a number of existing links, retained a SKI association through all three stages, and self-directed his/her learning by acquiring elements not previously taught. Brook's apparent focus on the development and maintenance of the skills-knowledge and knowledge-identity element pairings resulted in a more gradual development of the remaining element pairs. This is evidenced by the weaker link-weights in stages two and three. Although complete connectivity of element nodes was not established, Brook made adequate progress towards developing the epistemic frame of a computer game programmer.

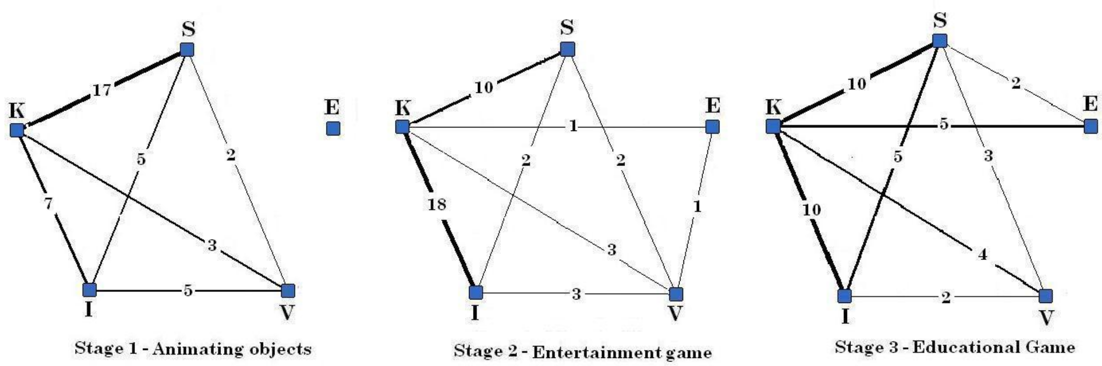

Figure 8. Brook's epistemic network graphs.

Ashley's ENA Graphs

Ashley's ENA graphs (Figure 9) suggest that epistemic frame development occurred gradually through stages one and two and advanced noticeably in stage three. Unlike his/her classmates, Ashley's focus in stage one was exclusively on the development of the skills and knowledge elements as evidenced by its strong link-weight. His/her progression through stage one was consistent with the expectations for the stage.

Stage two ENA graphs suggest a cautious expansion towards using other frame elements. The SKI association evidenced in this stage supports that Ashley's perception of learning was evolving beyond acquisition of basic skill sets. Ashley's most obvious learning gains occurred in stage three as evidenced by the increase in links and stronger link-weights. Although Ashley's progression towards epistemic frame development occurred more methodically, by stage three s/he had achieved comparable results.

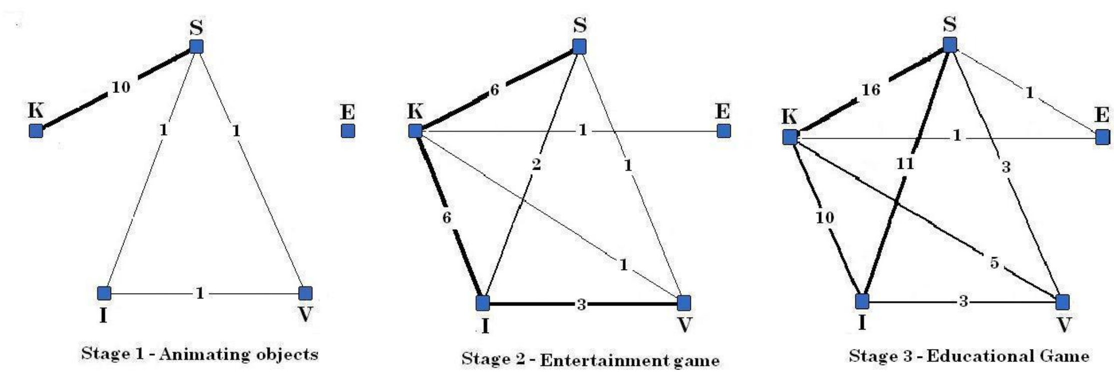

Figure 9. Ashley's epistemic network graphs.

ENA Results Summary

A number of noteworthy patterns emerged from stage one ENA. First, all students focused on skills and knowledge acquisition in the first stage as was demonstrated by the strong link-weights. This was expected as cognitive development involves the progression from concrete to abstract operations

(Bastable & Dart, 2007). Emphasis on the acquisition of fundamental skills and practices is developmentally appropriate as it forms the basis of early learning and is the foundation for further learning.

Second, students extended their learning to other frame elements only after they established strong link-weights in the skills-knowledge, knowledge-identity and/or skills-identity element pairings. In most cases, the development of the remaining frame elements or the order in which they occurred had little to no effect on the strength of existing links. Epistemic learning provided students with sufficient flexibility in allowing them to decide how they learned and the depth of that learning.

Third, students were beginning to take a multi-faceted approach to learning through the cultivation of strong multiple node links (e.g., the skills-knowledge-identity association). In establishing interdependency between three or more nodes, students demonstrated they could expand their ability to think and learn. The multi-faceted approach to learning allowed students to further enhance their personal epistemologies and advance their metacognitive awareness. According to Bendixen and Hartley (2003), students with more complex beliefs about knowledge and more advanced metacognitive awareness fare better and gain more knowledge.

Lastly, epistemic frame acquisition was achieved by most students as all frame elements were activated at least once during the study stages. The lone student who had fallen short required only one link by stage three to achieve a full epistemic frame. ENA supports that aspects of students' epistemic frames became more robust the longer they participated in the epistemic learning environment (Shaffer et al., 2009). Epistemic learning resulted in positive outcomes for students as it created the conditions that made learning accessible and achievable.

Stage One - Early Epistemic Learning

In the early epistemic learning stage, students familiarized themselves with the responsibilities and expectations of a game programmer by mirroring the cognitive, behavioral and attitudinal practices of members in the game programmers' community of practice. A lesson-assignment strategy was utilized that permitted students to learn and apply different skill sets in solving real-world problems while simultaneously developing the principles of practice of a game programmer. It was through a lesson-assignment scaffolding of new concepts and practice-specific endeavors that students constructed their game programmer personas (Manitoba Education, Citizen, and Youth, 2007).

Lesson activities gradually introduced students to the fundamental concepts that game programmers required to complete programming tasks, acquainted them with problem solving techniques needed to overcome coding obstacles, and provided them with sufficient opportunity to achieve skill set competency prior to challenging assignments. Student learning was advanced in lessons through an editing technique referred to as modding. Modding is a departure from more traditional approaches to teaching programming as concepts are learned in relation to other concepts rather than in isolation (Foreman, 2004; Lankshear & Knobel, 2008). Modding also allowed for intentional omission of certain details as a strategy to promote deeper thinking through the processes of analysis, evaluation, and adaptation of programs (Prensky, 2007). This editing technique permitted students to learn the technical components of programming without burdening them with matters concerning program design and development.

Through assignments, students participated in the real-world practices of game programmers. Assignment activities provided the platform from which students could engage in the role-play and identity exploration of a computer game programmer by consolidating their prior learning from lessons in challenging well-ordered problems, exercising initiative in overcoming problems and learning new strategies, and demonstrating the ability to work independently and/or collaboratively. Role-play and identity exploration are well-established, low-risk learning techniques that are known to contribute to the intellectual, emotional and physical growth of young learners (Gee, 2007, 2008; Lee & Hoadley, 2007; Lombardi, 2007). Through role-play and identity exploration students experienced the expert thinking common to computer game programmers.

Expert thinking is known to improve as learners confront problematic situations and resolve them independently or with a little assistance (Birse, 2009; Kraljevic, 2011). Success on lessons prefaced higher quality assignments and higher quality assignments served as a positive indicator that students were capable of expert thought (Manitoba Education, Citizen, and Youth, 2006).

Stage One - Teacher Observations and Student Reflections

In stage one, observational and reflection data revealed that students were at the formative stages of developing the behavioural characteristics of a computer game programmer. All students demonstrated a capacity to think and practice like game programmers by acquiring many core skills associated with the game programmers' community of practice. Several individuals also augmented their learning by acquiring supplemental skill sets. Individual and group learning permitted students to learn both independently and cooperatively as members of a community while still maintaining a degree of individuality (Monghan & Columbaro, 2009). Group learning, based on the acquisition of core skills, ensured that a community of practice functioned as a group while individual learning allowed members to differentiate themselves within the group.

Group Learning

Interacting with code. A characteristic shared by all computer programmers is the ability to interact with the program code. Interacting with code involves a cyclical reasoning process where programmers apply and adapt command codes until a desired effect is achieved. Observational, reflective and ENA evidence supports that students routinely engaged in the process of code interaction.

Throughout the first assignment, students were observed interacting with their code as they self-evaluated and edited their programs, addressed coding choices, applied heuristic problem solving strategies, and persevered through coding difficulties. Evidence provided by ENA work samples supports that students were interacting with their code via entering, modifying and executing code, debugging for errors, and/or integrating new code into existing code. Through persistent code interactions, students became proficient programmers as they reinforced basic programming skills and problem solving strategies.

Students' reflections support that conceptual awareness was expanded by analyzing the relationship between commands and their effects and the manipulation of those commands to achieve a desired effect.

> Jordan: I wanted a variety of different shapes so I substituted *sphere* for other shape names.
>
> I changed the rotation speed of a shape by changing the pitch, yaw and roll numbers.

> Lorie: Today, I tried to put wallpaper on the background. I did this because I was trying to learn how to make a midground, background, and foreground. I was thinking ahead.

Alex: I helped a person debug and correct their code by finding their error and telling them the code they needed.

I looked up the code for creation of different objects and added them to the area. I then made three shapes rotate.

Students used code interactions to fully explore command function and applied this knowledge to achieve results beyond the assignment expectations. Interacting with code also taught students to exercise critical reflection, patience and persistence in programming. The level of interaction became more pronounced as students improved their skill sets.

Knowledge production. Programmers also share the characteristic of being producers, as well as consumers of knowledge. Observations revealed that students were engaging in knowledge production by extending their learning beyond the course curriculum in learning new ideas and/or creating unique programs. Specifically, students were observed experimenting with parameter values to create non-primitive objects (e.g., cuboids, octahedrons), constructing complex objects through the overlapping of multiple objects (e.g., cars, flowers, buildings), and incorporating elaborate movements by rotating objects around multiple axes (e.g., simulating flying by moving along the x, y and z axis). The combination of these effects enabled students to create sophisticated and elaborate animations.

Students' reflections emphasized how knowledge production took the form of improvements to and personalization of existing programs through the manipulation of existing commands or application of new commands.

> Jordan: The cone wasn't very pleasing being chunky. To smoothen the cone, I put the number 32 into the brackets beside CreateCone.
>
> Wanted light to act differently. Tried different types of light and played with its range. Made light have an interacting effect on solid colored objects.
>
> Lorie: I learned how to overlap most shapes in Blitz to make a new image. I could make more elaborate images by overlapping shapes and colors. This effect was created through experimenting with the code until it made sense. The two commands I experimented with included ScaleEntity and PositionEntity.
>
> Brook: I wanted to reposition the shapes into a triangular formation. I experimented with the PositionEntity command to achieve this.

A deeper conceptual understanding of commands and a willingness to enhance programs by learning additional programming constructs gave students more flexibility and freedom in choosing how to use their knowledge and manage their learning (Longworth, 2003; Medel-Añonuevo, Ohsako, & Mauch, 2001).

Complementary knowledge. Learning to game program often entails drawing on knowledge from other domains. Today's computer programmer operates from an inter-disciplinary approach were s/he may be required to think like a mathematician, a physicist, an athlete, a musician and/or an artist. Interdisciplinary studies are particularly engaging for students because they focus on questions and matters of relevance (Kaskey-Roush, 2008).

Observational data provided perspective into students' use of complementary knowledge in enhancing their programming skills. Observations revealed that students used their mathematical understanding of the Cartesian co-ordinate plane (i.e., 2-dimensional space) to deduce positioning in the Euclidean plane (i.e., 3-dimensional space) and their mathematical reasoning in applying trial-and-error problem solving strategies in determining object size, shape, positioning, structure and rotation. Also, students' artistic thought was demonstrated in their use of graphic editors to edit images through skewing, stretching, or rotation. Evidence provided by ENA work samples supports that students applied mathematical aptitude in learning 3D perspective and object creation and manipulation, artistic ability in creating 2D images and texturing 3D objects, and technical prowess in integrating effects across multiple applications.

The emphasis on complementary knowledge resulted in students learning Blender to create and export 3D models, Audacity to edit and arrange music, and Adobe Fireworks and/or Paint to edit images. As well, students used their established knowledge in mathematics, science, and art to enhance their special effects. The integration of multiple knowledge bases into programming allowed students to reinforce prior learning, experience the multi-faceted nature of computer programming, and appreciate the importance of a diverse education.

Personal agency. Observational and ENA data provided evidence of students influencing the outcome of their learning experience by taking ownership of their work and assuming responsibility for their decisions. Each student exercised personal agency by creating highly individualized programs that reflected his/her preferences and interests (e.g., choice of texture, size and shape of object, movement of object, supplemental special effects). This required students to assess the effect they wished to incorporate and manage the learning required to produce the effect.

Students were also observed taking agency in developing their individual programming styles and techniques. Students assumed responsibility for the choice of formal procedures, organization of program code, detail of documentation, and program augmentations. Some had organized the code by effect while others by function. Students' programming choices ensured that their programs were functional but also meaningful.

Developing program style and technique provided students with a sense that their work was truly their own.

Personal agency was most evident when students became self-directed learners. Self-directed learning is an important development step that prepares an individual to become a lifelong learner (Collins, 2009). As self-directed learners, students exerted free will in the choices they made and the paths they followed in becoming game programmers (McLeod, 2007).

Individual Learning

Individual learning occurred as students desired to differentiate themselves from other game programmers. Students often advanced their learning to replicate the features and effects found in commercial video games. The following examples represent a collage of the individual learning experienced by specific students as gathered by observations, reflections and ENA work samples.

Lorie focused on making his/her code more efficient by taking advantage of coding shortcuts to improve program execution. S/he learned the shortcuts by referencing the Blitz 3D on-line manual and through experimentation. The combination of different learning strategies (i.e., research and discovery) effectively helped Lorie to make connections that were not otherwise obvious.

Jordan's use of descriptors such as "chunky", "smoother" and "interacting" suggests that his/her learning was focused on making the objects aesthetically pleasing and the program output more visually appealing. ENA of Jordan's program also revealed that s/he had adopted the programming practice of using library code. This strategy allowed Jordan to find efficiencies in programming. Students who became efficient programmers often used the time saved to work on improving other aspects of their program.

Ashley emphasized the use of descriptive variable names. In doing so, s/he had applied a programming convention that made the code more meaningful to him/her and to other programmers. The use of programming convention also simplified coding for Ashley because the descriptors s/he used were short in length and easy to remember. Learning programming conventions is significant as it ensures that all programmers abide by standardized practices that simplify the programming process (Hutcheson, 2011).

The individual learning experienced by some students suggests they had a more comprehensive view to programming that extended beyond the simple entry of code to include planning, design and development. The individual learning experienced by these students subsequently became part of the public domain as they shared their knowledge with others.

Stage One Reflections

At this early stage, students were amenable to the idea of learning from the perspective of a computer game programmer. An analysis of stage one ENA graphs suggests that students focused their learning on acquiring the skills and knowledge characteristics but were also beginning to explore other aspects of the game programmer experience. As students were only provided with a rudimentary understanding of a game programmer's epistemic frame, their ability to think, practice or act as game programmers was being advanced intuitively through independent research and/or by collaboration.

The skills and knowledge association established by all students confirmed that learners still had a preference for learning fundamental skill sets above all else and that these skills were essential in helping them to progress. This is evidenced by the strong skills-knowledge bond in each student's ENA graph. This learning advance was expected because the very nature of knowledge construction requires that individuals begin with concrete operations (Bastable & Dart, 2007).

An unexpected and interesting development was the SKI association that most students established in stage one. Establishing the interdependency between characteristics represented a significant learning advance as students had not yet been exposed to the influences of identity on learning, were only beginning to examine learning from multiple perspectives, and were in the emergent stages of identifying with game programmers. The fact that identity development occurred early in the epistemic learning and was established before other characteristics suggests that identity is as influential to learning as are skills and knowledge.

The students' learning advances were predicated on their willingness to participate in learning from a multi-faceted perspective and to adapt their way of thinking. Analysis of observational and reflection data revealed that students were developing a sense of social presence within the community of game programmers by adopting the thinking and practicing characteristics of game programmers (Lankshear & Knobel, 2008).

ENA graphs, observations and reflections provided insight into the extent to which students were engaging in the epistemic learning of a computer game programmer. As most students had met or exceeded expectations for this stage, it appeared evident that they were embracing their roles as computer game programmers. Although this stage was mostly teacher-directed and students were expected to achieve specific outcomes, the principles students learned and the order in which they learned them was unpredictable. Students did emphasize skills and knowledge development in stage one but not to the exclusion of other qualities. In epistemic learning, there was no formula to dictate priority or progression.

Stage one was primarily teacher-directed by virtue of the instructions provided, the structure of lessons and assignments, and the teacher-student interactions. While some students exercised initiative in dealing with programming challenges, most depended on the teacher for assistance.

Although some students' development exceeded expectations, this stage fell short in providing them with a richer immersive experience that included more opportunities to explore the game programmer identity, greater involvement in deciding the project outcomes and expectations, increased occasion to collaborate and contribute to group intelligence, and the programming of an actual computer game. Stage two focused on addressing these issues.

Stage Two – Expanding the Epistemic Learning Experience

In this stage, students continued cultivating their epistemic frames by addressing how identity guides praxis. Lee and Hoadley (2007) assert that through identity adoption, students are exposed to new perspectives and are challenged to think in different ways. In evolving their identities as game programmers, students took actions based on a broader understanding of their roles and responsibilities as members of a community of game programmers. To promote identity growth, the adaptations to this stage included focusing learning on identity-centered actions, promoting exchanges between students by emulating real-world game programmers' environments, and engaging students in experiences that more accurately paralleled authentic game programming practices. Although the emphasis in this stage was on identity, students were encouraged to reinforce previously acquired characteristics and to progress as necessary.

To shift the focus of learning to identity, students were requested to examine a modified Pea and Kurland's (1984) Skill Level chart (Appendix F) and categorize each action according to the behavioural traits of thinking, practicing and/or acting as a game programmer. Results were examined and discussed in class to isolate actions that represented the identity characteristic and others that were open to interpretation. Observable actions consistent with the actions of game programmers qualified as an identity characteristic. The chart aided students in aligning their actions with the epistemic characteristics they were developing.

In creating an environment that more accurately emulated a game programmer's environment, an instructional strategy of teacher-as-mediator was adopted. The teacher's role in this situation was to mentor and guide students' learning using the probing learning principle. Gee (2008) defines this principle as a cyclical process of doing something (i.e., probing), reflecting in and on the action, forming a hypothesis, re-probing to test the hypothesis, and then accepting or rethinking the hypothesis. Teaching became a consultative process and learning required that students place added emphasis on using the teacher and other students as resources (Johnson, Adams & Cummins, 2012). To encourage students to interact and collaborate with other students, the more traditional rules of conduct were relaxed. A learning environment that places greater emphasis on distributed intelligence reinforces that learning as a community benefits all its members (Birse, 2009; Christiansen, 2010).

The final adaptation challenged students to enhance their programming competencies by making them responsible for the development and personalization of a computer entertainment game. Rather than programming by specific instructions, students created their game from a descriptive interpretation of its objectives, features, and special effects. All games shared common characteristics but also included personalized preferences. The combination of developing a practitioner's habits-of-mind, participation in a community of practice, and the challenge of real-life problems created an immersive learning environment that allowed students to fully explore their alternate identities as computer game programmers.

Stage Two – Teacher Observations and Student Reflections

Observations and reflections revealed that students had made pronounced learning gains in identifying with game programmers but also had begun developing the value characteristic. Students repeatedly demonstrated that taking actions in programming required that they also consider the need for and importance of the action. While the simultaneous development of the identity and value elements was not anticipated, it was hardly a surprise. The epistemic frame advances occurred predominantly as students engaged in skill enhancement, programming decisions, and group exchanges as they interacted with their games and the game programmer environments.

Reflections support that students were identifying with game programmers as their thoughts expressed many of the actions consistent with game programming practices. Actions included persistence with coding issues, using heuristic problem solving strategies, seeking help from others or the command reference manual, experimenting with values until the effect was achieved, and adapting their conceptual understandings. The quality of the students' reflections also demonstrated that students were functioning at a higher cognitive level.

Jordan: What I found challenging was converting some of the code in the lessons to my game so it'd work the way it's supposed to. I'd need to keep trying until the code worked properly.

Lorie: The easiest thing about entertainment game is creating the planets. The hardest is the hit detection. Today I tried to get a medium planet (earth) to orbit around a large planet (sun) while at the same time have a small planet (moon) orbit around the medium planet. I did not understand how to get the moon to orbit around the earth so I asked people around me and then I checked the command reference. I have still yet to find the solution but I am getting close.

Brook: Created the rings of Saturn by adding a sphere and changing the scale properties to make it flat. Combined the rings with Saturn through positioning.

Forward and backward movement of an object was achieved by changing the x# and y# properties to certain numbers to move the object depending on the key pressed.

How to fix collisions? Finding trouble with adding code for collisions. Rearranged codes, codes were in the wrong place.

Ashley: My sun was too small so I made it larger. I used trial and error to find the right numbers needed to make the change. I used this approach with other objects so my objects would look more accurate. The most challenging aspect of the game is all the different things going on at once, it's distracting.

Students' identities as game programmers were further enhanced as they considered their options and the consequence of their choices. Students were observed consolidating lesson concepts directly into their entertainment game and forgoing the extra step of completing the lesson. This decision allowed students to devote extra time towards developing their entertainment games. Students continued to respond as computer game programmers in deciding to incorporate dominant design principles into their entertainment game to produce keyboard controlled play-action. The students' decision to include keyboard control was based on their desire to emulate the practices of professional game programmers.

The juxtaposition of role-playing with game playing created an amplified learning experience for students that enhanced their game programmer identities. Observations revealed that students' exercised deeper reflection and an ability to adapt their thinking through a process of playing the game, learning what was needed to improve the game, applying the learning, and then repeating the process. Identifying with the game as a player allowed students to progress their identities as programmers because they understood that to increase the appeal of the game they needed to consider the programmer's actions in improving the game.

The creation of an entertainment game advanced group identity as students shared their gaming experience with others. Through a process of peer evaluation, students improved their games by adding features suggested by others. Learning gains became more pronounced as students increased the appeal of their game based on the expectations of others who played the game.

The teacher assistance provided to students in this stage was intended to stimulate the range of thinking required in real-world game programmer communities of practice. As my role was consultative, a method of maieutics (i.e., answering a question with a question) was used to inspire students to think for themselves. Students became independent thinkers and active learners by applying the probing learning principle rather than expecting the answer overtly. Self-sufficiency contributed to improving students' retention and recollection and made the learning experience more meaningful (Swartz, 2008). Observational and reflection data support that students were becoming deeper thinkers as they routinely challenged and overcame programming problems. ENA data also corroborated that students were becoming self-directed learners based on their ability to learn epistemic frame characteristics independently.

Stage Two Reflections

It was evident from the interactions students had with their games and the gaming programming environment that they were immersed in the game programmer experience. Students regularly allowed their actions to be guided by the epistemic frame qualities they had acquired. This was evidenced by students' willingness to manage their own learning, take ownership of their work, decide on courses of action, and to work as a community. Learning from an identity and values perspective also served to reinforce students' previous learning.

ENA graphs for stage two revealed that focusing on identity assisted students in progressing towards full epistemic frame development. Most students either strengthened or maintained existing associations and all students continued to establish new associations. The increased strength of the SKI association by most students and the increase in identity and value related associations by all students suggest that their understanding of the dynamics of learning was transforming and their mindsets were evolving.

The epistemic learning environment allowed for a greater level of achievement if the students desired it. The amplified programmer/player learning experience resulted in increased levels of motivation and engagement as evidenced by the final outcome of their entertainment games. Some of the elaborate special effects that students conceived included the creation and integration of unique 3D models, first-person or third-person player views, movement of objects along all three axes in real-speed and hyper-speed, artificial intelligence, environment orientation and movement, and sound effects. The uniqueness of each student's game was only limited by the extent to which they chose to include special effects.

Students developed a sense of accomplishment in incorporating new ideas into their program and were eager to share them. As group interactions increased, a more efficient method of idea distribution had to be devised. A Google document form was created (Appendix G) that allowed students to voluntarily submit their ideas. The quantity and quality of the contributions reaffirmed that students thought of the class as a community and that all could benefit through shared learning (Johnson, Adams & Cummins, 2012). Social construction of knowledge assists in enhancing the social presence and self-esteem of all community members (Monaghan & Columbaro, 2009; Sword & Leggott, 2007).

In stage two, significant epistemic frame development occurred when students were provided with a degree of freedom in determining the depth and scope of their learning (Appendix H). By the end of this stage, one student had acquired the complete epistemic frame of a computer game programmer and the remaining students achieved near-complete epistemic frames after having established a majority of the links (i.e., of a possible ten links, one student achieved nine, two achieved eight, and one achieved seven). Students' epistemic learning was occurring intuitively as they relied on their own ingenuity in learning and acquiring the principles of practices of game programmers.

To more accurately experience the game programmers' reality and to further enhance epistemic frame development, students needed to be immersed in more real-world programming practices. Stage three addressed these issues by engaging students in the experience of being software developers.

Stage Three – In situ Epistemic Learning

Stage three was adapted to provide students with the opportunity to genuinely experience the demands and expectations placed on software developers. In this scenario, students were responsible for creating an educational game for a client within a given time frame. Creating a game for a third party was an incremental step designed to allow students to experience programming that takes into consideration the needs of others. Epistemological awareness was developed by having a third party hold students accountable for their decisions and actions. Throughout stage three, students continued enhancing and/or reinforcing their epistemic frames.

To assist students with the formulation of a game, a teacher-directed software development planning session was conducted to allow them to conceive an idea for a game and to devise a programming strategy. Teacher input was required due to the absence of an actual client base. During the planning session, students shared their ideas and plans to which I provided feedback until approval was granted to begin programming. The software development session ensured that students chose to create a game that was manageable and within their current programming capabilities.

To further authenticate the game programming experience, I assumed the role of a client once students started programming. As the client, I represented the interests of a third party and reserved the right to request program modifications and/or adaptations. Students maintained the rights to the creative programming process but the game became the shared property of the client and programmer. Students willingly accepted this condition as they recognized that real-world programming is almost exclusively done for third parties and that the experience more accurately emulated real-world practices.

Students were encouraged to work as a community of programmers by sharing their personal expertise with others, working collaboratively when requested, and taking advantage of available online resources. A project management approach was implemented to ensure students stayed on task and completed work according to schedule.

Stage Three – Teacher Observations

Most students chose to create an educational game based on the modding of an existing game. Relying on the modding process demonstrated that students had acquired a strong conceptual awareness of the programming constructs and structures, the ability and confidence to create new programs by modifying existing code, and the skill sets to be efficient and effective programmers. The modding strategy also permitted students to focus their attention on programming the educational aspects of their games rather than on learning new programming constructs. In the end, the decision to modify or create depended on the extent to which students wanted their game to be original.

Students faced considerable challenges in the design and development of an educational game. Although all students had strong technical skills, most struggled with the pedagogical aspects of the game as they lacked the educational expertise to appropriately structure and sequence the learning experience. The end result for most students was a form of edutainment game (i.e., educational entertainment) rather than a true educational game. The programming of an edutainment game was hardly a wasted effort as students developed an appreciation for how difficult it was to program genre-specific games.

The extent to which students' thinking was transformed was evidenced in the manner in which they approached the design and development of the educational game. First, students' thoughtful participation in the game planning process demonstrated their commitment and conviction to creating a meaningful educational game. Many had the confidence to attempt a program that exceeded their technical programming capabilities because they believed they possessed the skill sets to overcome difficult challenges. The confidence level of students was not surprising as many had exceeded lesson and/or assignment expectations and considered it to be an accepted and valued practice. In the end, students agreed to create games that were appropriate for or slightly above their skill levels.

Second, students adopted the practice of maintaining high programming standards to ensure that the gaming and programming experiences remained consistent for others. Students conformed to dominant design principles in coding animation and action, applied programming conventions in making variables comprehensible and logical structures easy to interpret, and included documentation to explain coding purpose and effect. By observing established programming standards, students' programs were properly organized, functioned efficiently, and remained accessible to other programmers.

Third, students exercised diligence and patience in meeting the needs of their client regardless of the additional code interactions that were required. All students were receptive to the modifications and adaptations because it allowed them to demonstrate and/or expand their programming competencies and provided them with the opportunity to enhance their programs. Considerable satisfaction was gained from fulfilling the task and knowing that their improved game benefitted others.

As the sharing of code was impractical due the uniqueness of each program, students worked collaboratively to impart ideas and offer suggestions. Construction of the educational game inevitably became a group project that required students to depend on one another for programmer insight, expert advice and user opinion.

Stage Three - Final Reflections

Students' epistemological learning gains during this stage were minimal as they struggled with the educational decisions and actions associated with the creation of an educational game. The epistemological aspects of the entertainment game were less troublesome for students as their decisions were governed only by how well the game played. The epistemological aspects of the educational game were more complex because the game not only needed to play well but also had to be constructed on solid learning principles and appropriately sequenced learning activities. The students' commitment to learning the epistemic frame of a computer game programmer was not derailed because of their struggles with epistemological considerations. Rather, it challenged students to advance their learning within the limitations of their current knowledge (Csikszentmihalyi, 1997; Vygotsky, 1978).

During this stage, the robustness of each student's epistemic frame improved mostly by virtue of the newly established links and marginally due to the strengthening of existing links. A quick comparison of each student's ENA graphs shows that four of the five students had established a majority of the links by the end of stage three and that a convergence of their stages two and three ENA graphs supported full epistemic frame acquisition (Appendix H). The only student who did not acquire a full epistemic frame in stage three still achieved eight of ten associations between epistemic frame elements. For this individual, epistemic learning occurred primarily between stages two and three. The fact that all students were developmentally comparable by the completion of stage three suggests that epistemic learning was effective in meeting the needs of all students and that it allowed them to progress according to their abilities.

Student Interviews

The final words of reflection were provided by students in their responses to interview questions. Interviews were conducted with students to allow them to provide perspective on their growth as computer game programmers. Responses to questions #1, #2, and #3 were combined into one answer to better assist with data organization and analysis. Students' answers were paraphrased and arranged in table form to ease readability (Table 7) and to allow for analysis by individual and by category.

Questions #1-3: ***Describe how you think, practice, and act like a game programmer.***

Table 7

Student Responses to Interview Questions #1-3

Student	Think	Practice	Act
Alex	But there's more or less a generic way of how game programmers think. And that's basically to see how I can get the best out of it so that it won't hamper the users' experience, the programmer's experience, the program, or the system.	Practice is just inserting code that's more useful to you than to any other person, and does not require too much thinking.	It is just something that happens by reaction or instinct. I can control it but it's more likely that it is done in a way that is more comfortable for the user.
Lorie	It's kind of the same thing as practice. I think about the code and how it will fit together and help with other features.	I looked at some of the code and I played with the code in Blitz3d and I messed around with it and saw what certain lines do and what certain actions do. I used the guide that also comes with Blitz to see what the command would do.	I would try to make my code as efficient as possible by making it compact. I would constantly save and run my work to see if things would work and I wouldn't erase code and I made a lot of backups so I didn't have to do any rewriting. I would copy and paste everything.
Ashley	I learned how to problem solve. When I came up	Practice is mainly writing code and reasoning while	Acting would be coming up with ways to make my code do

	with an issue in programming, I used to get stuck a lot. It helped me try to think through things myself and not always go to the teacher.	writing code. By reasoning I can make it happen.	things. My original code was based on something but I changed it and morphed it to something of my own.
Brook	I think by going into depth in coding when troubleshooting. I think more in depth about what the code is and what it's doing. For example, if I want to customize a code and say it's a simple sphere but I want to add more motion into the sphere or maybe add a description or texture to it, I have to think about what the code does and if I want to add to it.	Being able to write codes and demonstrating code modifications but also instead of coding going into the real world and playing other games that give me ideas on how to customize my code. Persistence - if I have an obstacle that I can't figure out right away how to do it, I leave it off to the side for a bit and then once I have more skills and understanding I go back to it. I had to consider what other people would like in the program or game.	I act by customizing my code. I like to practice at home on my own time to research references from other people about what they added. If my code doesn't work I like to practice it and look at other people's code and see what I have to add to my own code and modify it.
Jordan	Most of it I think was solving problems while entering the code. I found that was a very common thing and I just kept thinking about how I wanted to change things to make it	The practicing was the repetition of just entering the code, using and reusing much of the similar code, and troubleshooting. Sometimes I ran into a problem once and then it came up again and I	Acting is pretty much making your own game. I got to make my own game and doing the coding and the modding which is pretty much what game programmers do. The whole process felt like I was acting like one with

	my own and just knowing what everything does. What certain lines of code do and how I can change them. I started to just know how everything works.	remembered I did this before so then I knew how to fix it the second or third time it happened. Because I did so much of the other stuff it slowly built up.	deadlines and having the theme of making a game. I felt more like a game programmer from industry because we weren't just programming, instead we were doing it because we wanted to make the games our own.

Analysis of Individual Responses

Analysis of individual responses assisted in establishing students' perspectives on the experiences that influenced their growth as game programmers and the extent to which these experiences shaped their identities as game programmers. Distinct experiences represented the individual learning gains while shared experiences represented the collective learning gains.

Alex's game programmer experience entailed being an efficient programmer but also being mindful of client expectations. His/her comments demonstrate a more comprehensive understanding of the roles and responsibilities of programmers ranging from code entry to software design and development. Alex's efforts to address every aspect of the game programmer experience supports that s/he internalized a game programmer's epistemic frame (Pea & Kurland, 1984; Shaffer, 2007).

Lorie perceived the game programmer experience to be about developing proficiencies and efficiencies with programming through the processes of analysis, reflection, and adaptation. His/her comments focused on the application of best practices in making programs functional. Through his/her time-saving actions and attention to detail, Lorie demonstrated how s/he identified with game programmers.

Ashley's reflections placed emphasis on the problem solving and reasoning facets of game programming. His/her perception of being a game programmer involved the application of these skills in overcoming programming challenges and in thinking independently and creatively. Ashley's tendency as a programmer was towards developing the skills that empowered him/her to create and write original programs.

Brook's remarks focused primarily on developing a deeper conceptual understanding of programming commands and constructs. His/her comments support that an enhanced conceptual awareness was achieved by linking knowing to doing through research and reflective practice (Bendixen & Hartley, 2003). Brook took a methodical approach to game programming that engaged all aspects of the programming experience and involved collaboration between programmer, expert, and user.

Jordan perceived the game programmer experience to be about problem solving and troubleshooting programs. His/her comments indicated that considerable code interaction occurred in achieving a desired result and/or creating a program. Jordan's emphasis on being a game programmer involved acquiring the strong technical skills needed to design, create and develop original programs.

The quality and the content of the responses demonstrated how students identified with game programmers as thinkers, practitioners or thinker-practitioners. The diversity in individual responses suggests that each student perceived the game programmer experience somewhat differently. Thinkers focused on problem solving, practitioners emphasized code writing and entry, and thinker-practitioners engaged in both. Students who considered themselves thinker-practitioners most closely identified with actual game programmers as they better understood the interdependency between epistemic frame attributes.

Analysis of Category Responses

An analysis of category responses assisted in establishing student perspective for each category. Individual perspectives provided insight into personal development while a shared perspective was taken as an indicator that students were developing a common mindset.

Many of the student responses expressed similar views but not always in the same categories. Some degree of overlap was expected as each student interpreted thinking, practicing and acting as game programmers differently. When responses were examined conjointly, evidence existed to support the emergence of a shared mindset.

Students agreed that they thought like game programmers as they utilized a variety of thinking skills in problem solving and troubleshooting coding issues. Their comments suggest that reflective analysis, adaptive thinking, recollections, inquiry, and/or experimentation strategies were used to develop a deeper conceptual understanding of commands and to solve problems through a multiple pathways approach. Students shared the perspective that thinking like a game programmer involves applying the necessary logical reasoning strategies to overcome programming challenges.

Students indicated they practiced like a game programmer by applying commands and procedures in making programs functional on different levels. Their responses support that practice involved a process of analyzing, entering, and executing program code. Practicing, when applied to finding solutions, required students to consider objective details such as what is the correct form for a command, what does it do, and what are its limitations. Students perceived practicing to be synonymous with learning the technical skill sets of game programmers.

Students' responses suggest that acting like a game programmer occurred most when they were interacting with their code and that it entailed every aspect of the game programmer experience including thinking and practicing. Students' code interactions were meant to serve different purposes ranging from simple code manipulations to complete game creation and allowed them to distinguish their work from one another. The diversity in responses supports that students perceived acting like a game programmer to be a unique endeavour based on their interpretation of events and experiences. It was through acting like a game programmer and experiencing game programming that students knew and understood what was required to be a game programmer (Lopez, 2001).

Although students were acquiring the game programmer skill sets as individuals, the data suggests that they were also becoming members of the game programmers' community of practice. A shared ability to interact with their program, resolve coding issues, and create programs supports that students were experiencing learning as a community. Group learning was anticipated as a community of practice requires that all members acquire the community's principles of practice (Shaffer, 2007).

Analysis of Epistemic Learning

Students' opinions of epistemic learning helped in establishing its practicality and effectiveness as an alternative learning environment based on its ability to motivate and engage students.

Question #4: ***Which features of learning like a game programmer did you like best?***

Alex: It's more of hands on stuff rather than theory. You can actually get into the experience again right away and it's a simulation of what being a real game developer is like. Many software companies allow you to do almost anything and that is what happened here. It worked well and it's the right way of teaching people, that's for sure.

Lorie: What I really liked about it was the freedom and that I could take responsibility for my own work. You gave us a vague outline of the assignment and then we added to it, played around with it, made different features, and made it our own. It was not just a full assignment where we had to follow it word by word.

Ashley: I enjoyed that I had more freedoms in taking my program where I would like to take it. I can explore different things that I thought would be neat. It wasn't so directed and forced, it was more how you feel. I also enjoyed the fact that with the exploring I felt like I learned more rather than just taking the teacher's code and redoing it.

Brook: What I really liked was the self-reviews about what I learnt. For the first reviews, I would suggest simple stuff like adding certain code. But now, if I look back on it with my skills and experiences, I can say, I can add this and that from what I had before, like more in depth thinking, more acting and practice of course.

Jordan: It was the freedom. There weren't really too many limitations other than what you knew about what you wanted to do. For the final game, we had more freedom because you weren't exactly restricting us. In the end, everyone's game looked different which kind of showed our individuality more. It was more our flare on it and I thought it made everything better. I also liked making programs that actually worked**.**

Learning environments structured to give students more freedoms and greater responsibility for their own learning are consistent with current pedagogies on teaching students in the digital age (Brown, 2002; Lombardi, 2007; Shaffer, 2008; Sontag, 2009; Sword & Leggott, 2007; Wilen-Daugenti, 2007). The less-restrictive nature of the epistemic learning environment allowed students to experience learning from their own preferences and styles, to determine their own learning outcomes, and to express their individuality. The opportunity to design and develop an original project was significant for students as it gave them the opportunity to challenge their abilities and validate their learning. As is evident from the students' comments, the high-functioning nature of the epistemic learning environment was a very personalized experience.

Question #5: ***Which features of learning like a game programmer did you like least?***

Alex: The only thing that I didn't really like about this is the choice of language. There was very little documentation on line that can actually explain to you anything that you need. It's pretty difficult to actually get it to help.

Lorie: I guess the time; like if there was a year course. I don't know how that would play out because at the end of the year I didn't really have too much time to finish my final project. It was fun you know, easy, and there was almost no possible way to fail. You just had to really do the work. No, I don't think I really disliked this course at all.

Ashley: I sort of found that I wasn't very good at pacing myself. I think I didn't do so great because I felt I'm working on this code by myself. But I should have really scheduled it out a bit more. I didn't push myself enough necessarily.

Brook: I didn't really dislike anything besides having to write lots of code. If it's your goal to be a programmer then you have to go with it.

Jordan: Probably, not everything working out the first time because there is so much troubleshooting to it and just sometimes it got a little frustrating. But, once you got to the end and it worked it made it more rewarding. I liked this….it was way more fun to me. I got distracted at times but I tried to keep myself on track most of the time.

In the students' opinion, the freedom they enjoyed also served to impede their progress. A number of students commented that they had difficulty staying on task and found themselves distracted and unable to pace their progress. However, the attitudinal, behavioural and cognitive advances they made would suggest otherwise.

The dislikes shared by students represented personal issues that had more to do with their behaviour than the program. Three students shared their dislikes only to make a recommendation as to how the dislike could be addressed. Interestingly, while students were critical of themselves in matters dealing with the dislikes, they failed to give themselves credit for matters dealing with their likes.

Summary

The comments provided by students helped to establish which aspects of epistemic learning have educational potential and which might require reconsideration. Often, the success and effectiveness of a learning environment is contingent on the students' willingness to participate and engage in the environment. Analysis of the data from ENA, observations, reflections and interview responses supports that epistemic learning was an engaging environment that enabled students to thrive.

Chapter 5: Conclusions

This study endeavoured to answer the following three research questions:

RQ#1: *Does epistemic learning influence epistemic beliefs?*

RQ#2*: Which computer game programmer's epistemic frame qualities are acquired through epistemic learning?*"

RQ#3: *How does epistemic learning enhance learning in computer science*?

In response to RQ#1, it is reasonable to conclude that epistemic learning positively influenced individual personal epistemology as most students experienced an attitudinal shift towards a more complex position on knowledge. However, due to the absence of statistical significance, it would not be prudent to conclude that a causal or correlational relationship exists between participation in an epistemic learning environment and attitudinal shifts in epistemic beliefs. It must be noted that the students who participated in the study possessed a pre-established complex epistemological position and that this position was established in other instructional settings.

In response to RQ#2, it can be concluded that most students were successful in acquiring all epistemic frame elements. This is evidenced by the students' ENA graphs that support full or significant epistemic frame acquisition (Appendix H). The pace at which students acquired the epistemic frame elements and the order in which they were acquired varied from student to student. The varying robustness of each student's epistemic frame can be taken as an indicator that progression through epistemic frame element acquisition occurs individually.

In response to RQ#3, various data sources including ENA of work samples, teacher observations, and students' reflections and interview responses support that learning in computer science was enhanced. ENA of work samples illustrated the extent to which students extended learning beyond the assignment parameters, teacher observations provided a witness account of students learning computer science individually and collectively, and student reflections and interview responses offered insight into the depth of thought that students exercised in performing programming tasks.

Learning computer science was further enhanced for students through the acquisition of the epistemic frame of a computer game programmer. Possessing the complete or near-complete epistemic frame of a computer game programmer resulted in students having a diverse skill set and a broader understanding of computer programming. Epistemic learning was an effective and motivational environment in teaching computer science because it paralleled the real-world learning of computer game programmers.

Implications for Learning

Increasingly, the education system comes under scrutiny because of declining academic achievement levels and high dropout rates. The 2010 Pan-Canadian Assessment Program Report (Council of Education Ministers, Canada, 2010) revealed that grade 8 students in Manitoba experienced a decrease in achievement levels in English (mean = 478), math (mean = 468), and science (mean = 486) with mean scores significantly lower than the Canadian average (mean = 500). Furthermore, Human Resources and Skills Development Canada (2013) reported Manitoba as having the second highest dropout rate in Canada (i.e., Manitoba = 10.4%, Canada = 8.1%).

While these figures raise cause for concern because they imply that Manitoba students are failing to keep pace with students in other provinces, they also subtly urge teachers to adopt more effective teaching practices. Although epistemic learning is not intended to be the panacea for all the educational woes, it does endeavour to address the problems of waning student engagement and declining achievement levels by allowing students, individually and collectively, to become knowers and co-constructors of knowledge, culture and identity (Dahlberg et al., as cited by Paul-Sawatsky, 2012).

Impact on Student Learning

Epistemic learning holds promise as an alternative learning environment because of its needs-satisfying potential. This learning environment appeals to both the capable and struggling student because various intellectual and social needs are met through mastery learning, exercising intellectual rigor, immersion in disciplinary inquiry, development of relevant skill sets by solving well-ordered real-world problems, exploring alternate identities via low-risk role-play, establishing individual and group social presence through collaboration and/or becoming self-sufficient learners (Willms, Friesen, & Milton, 2009). Environments designed to foster success with learning on multiple levels tend to be more inviting and rewarding for students (Glasser, 1998; Sizer, 1997).

The General Learning Model states that learning is causally related to some aspect of a person (e.g., interests) and their situation (e.g., learning experience) (Buckley & Anderson, 2006). Epistemic learning creates the conditions for students to develop feelings and thoughts about how learning can be enjoyable through engagement in role-play and/or nested gaming. The ability for epistemic learning to engage students in immersive role-play results in them experiencing and enjoying learning much the same way they do when playing commercial role-play games.

Epistemic learning creates an atmosphere of inclusion where learning is supported through interdependence in a community. In this environment, learning becomes accessible and equitable for all as students migrate from peripheral roles to central roles and develop a sense of shared responsibility through mutual engagement in a joint enterprise (Christiansen, 2010). Through interdependence, students innately develop the community's caring ethos. Learning, guided by caring, becomes more purposeful as students make decisions and take actions based on a desire to improve their circumstances and those of others.

Impact on Teacher Professional Development

Sergiovanni (1992, p.53) asserts that "commitment to exemplary practice means practicing at the edge of teaching, by staying abreast of new developments, researching one's practice, trying out new approaches, and accepting responsibility for one's own professional development." Epistemic learning invites teachers to become teacher-practitioners by incorporating epistemic frames into the structure of their learning environments. Teaching from the perspective of a practitioner reinforces to students that knowledge must be both learned and applied. Being a teacher-practitioner is an unfamiliar role to many teachers that can only be cultivated through education and experience. This should not form an obstacle for the career-teachers or teachers-in-training as most epistemic frames can be learned independent of formal schooling through professional development, participation in a community of practice or both.

Standards of Validity and Quality

The methodological standards of judgment used to establish validity and quality in this study were those outlined by Guba (Mills, 2007). Guba establishes validity or trustworthiness in qualitative inquiry through an examination of the study characteristics of credibility, transferability, dependability and confirmability.

Credibility in my methodology needed to be addressed because the context-specific nature of my action research increased the potential for researcher bias. Prolonged engagement, persistent observation, triangulation, member checking, and referential adequacy helped to enhance credibility and to mitigate the possibility of bias in the collection and analysis of data.

Prolonged engagement was ensured as I taught my computer science class for a full semester. This arrangement gave me the opportunity to establish trust and build relationships with my students. Also, it allowed me to learn the culture of their setting and observe patterns of routine behavior to the point of being routine (Glesne as cited by Mertler, 2009). Persistent observation was practiced through a process of recording the events for each day, identifying the characteristics most relevant to the issue being studied, and examining them in detail. Such attention to my data collection activities provided detail and depth to my inquiries and helped in establishing adequacy, accuracy and appropriateness of my research materials (Stringer, 2008).

Member checking was conducted to allow study participants to examine their responses in verifying that the researcher accurately represented their perspectives and afforded them the opportunity to clarify and augment information related to their experiences. Referential adequacy was ensured as study participant viewpoints were recorded and reported in a terminology that was comprehensible to them. These strategies contributed to the reliability of the findings.

The small number of participants, the emphasis on a single grade, and the select choice of subject limited transferability of the study results. To enhance transferability, a detailed description of the context, events, and participants was provided. Such attention to detail allows others to judge the applicability of my research to their own situation (Stringer, 2008). The results of this study should be considered context-bound and may only apply to other similar contexts. Transferability of findings will depend on how closely other instructors are able to identify with my setting.

To address concerns of dependability and confirmability, a detailed description of the research process was provided, supplemented with an audit trail of all research information and processes. Dependability and confirmability were further enhanced through the triangulation of observational details, reflective replies, ENA of work samples, and interview responses. Triangulation allowed for the cross-checking and clarification of the collected data. The usefulness of ENA across different settings is still in question as it is used primarily in assessing epistemic frame development by players of epistemic games (Shaffer et al., 2009). Data gathered from ENA needed to be triangulated with other data sources to mitigate against inherent weaknesses in its research design. All data collected has been made available for the purpose of an external audit should the need arise.

Findings of this study are somewhat limited by the fact that the researcher worked alone in a self-study situation and used a small sample size. Findings are not generalizable, but rather may be transferable to other similar high school settings. Inter-coder reliability could not be established and interpretations were completed by one researcher; however, "peer debriefing" was used as a check on the interpretations.

Future Directions

Recommendations for Future Research

As a nascent pedagogy, epistemic learning has yet to be subjected to the rigors of analysis. This presents an exciting and interesting research opportunity for educators to examine epistemic learning from different quantitative and/or qualitative perspectives. Action research with a mixed-methods analysis was appropriate for this study as it was a self-study of my practices. The discussion of epistemic learning would be further advanced through research that replicates this study or applies other research designs.

This research focused primarily on a specific content area at one grade level. Further research of epistemic learning in different content areas and at multiple levels would assist in determining the appropriateness and broader application of epistemic learning. Such research could be conducted with a focus on the subject-related epistemic frame (e.g., accounting) or the content-related epistemic frame of a practitioner (e.g., accountant).

In this study, epistemic learning was researched for a limited duration. Longitudinal research on epistemic learning would help in establishing the impact on learning over prolonged periods. Such studies could focus on determining the effectiveness of epistemic learning along a continuum, the appropriateness of epistemic learning at different developmental levels, and the robustness of learners' epistemic frames as they continued to participate in epistemic learning.

ENA is an analysis method used predominantly in assessing learning while playing epistemic games. This study implemented ENA in assessing learning in an environment that carefully emulated the learning that occurs in epistemic games. The validity of ENA as an analysis method could be further enhanced through research that incorporates ENA into other educational settings.

Future Learning

Organizing classrooms to emulate real-world practices is not uncommon but neither is it pervasive. At first glance, the complexity of epistemic learning appears daunting for any educator, especially for those who focus on teaching prescribed outcomes. To make epistemic learning manageable, the depth of the epistemic frame to be taught must be left to the discretion of the teacher. Epistemic learning can constitute one lesson, a unit, an entire course, a complete program or a school philosophy. Organizing and managing the learning will depend on the extent to which teachers and the school desire an authentic epistemic learning experience.

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APPENDIX A –Gee's Digital Learning Principles

1) Active, Critical Learning Principle: All aspects of the learning environment (including the ways in which the semiotic domain is designed and presented) are set up to encourage active and critical, not passive, learning.
2) Design Principle: Learning about and coming to appreciate design and design principles is core to the learning experience.
3) Semiotic Principle: Learning about and coming to appreciate interrelations within and across multiple sign systems (images, words, actions, symbols, artifacts, etc.)
4) Semiotic Domains Principle: Learning involves mastering, at some level, semiotic domains, and being able to participate, at some level, in the affinity group or groups connected to them.
5) Meta-level Thinking about Semiotic Domains Principle: Learning involves active and critical thinking about the relationships of the semiotic domain being learned to other semiotic domains.
6) Psychosocial Moratorium Principle: Learners can take risks in a space where real-world consequences are lowered.
7) Committed Learning Principle: Learners participate in an extended engagement (lots of effort and practice) as an extension of their real-world identities in relation to a virtual identity to which they feel some commitment and a virtual world that they find compelling.
8) Identity Principle: Learning involves taking on and playing with identities in such a way that the learner has real choices (in developing the virtual identity) and ample opportunity to mediate on the relationship between new identities and old ones. This is a tripartite play of identities as learners relate, and reflect on, their multiple real-world identities, a virtual identity, and a projective identity.
9) Self-Knowledge Principle: The virtual world is constructed in such a way that learners learn not only about the domain but about themselves and their current and potential capacities.
10) Amplification of Input Principle: For a little input, learners get a lot of output.
11) Achievement Principle: For learners of all levels of skill there are intrinsic rewards from the beginning, customized to each learner's level, effort, and growing mastery and signalling the learner's ongoing achievement.
12) Practice Principle: Learners get lots and lots of practice in a context where the practice is not boring (i.e., in a virtual world that is compelling to learners on their own terms and where the learners experience ongoing success). They spend lots of time on task.
13) Ongoing Learning Principle: The distinction between learner and master is vague, since learners, thanks to the operation of the regime

of competence principle, must, at higher and higher levels, undo their routinized mastery to adapt to new or changed conditions. There are cycles of new learning, automatization, undoing automatization, and new reorganized automatization.

14) Regime of Competence Principle: The learner gets ample opportunity to operate within, but at the outer edge of, his or her resources, so that at those points things are felt as challenging but not "undoable".
15) Probing Principle: Learning is a cycle of probing the world (doing something); reflecting in and on this action and, on this basis, forming a hypothesis; re-probing the world to test this hypothesis; and then accepting or rethinking the hypothesis.
16) Multiple Routes Principle: There are multiple ways to make progress or move ahead. This allows learners to make choices, rely on their own strengths and styles of learning and problem solving, while also exploring alternative styles.
17) Situated Meaning Principle: The meanings of signs (words, actions, objects, artifacts, symbols, texts, etc.) are situated in embodied experience. Meanings are not general or de-contextualized. Whatever generality meanings come to have is discovered bottom up via embodied experiences.
18) Text Principle: Texts are not understood purely verbally (i.e., only in terms of the definitions of the words in the text and their text-internal relationships to each other) but are understood in terms of embodied experiences. Learners move back and forth between texts and embodied experiences. More purely verbal understanding (reading texts apart from embodied action) comes only when learners have had enough embodied experience in the domain and ample experiences with similar texts.
19) Intertextual Principle: The learner understands texts as a family ("genre") of related texts and understands any one such text in relation to others in the family, but only after having achieved embodied understandings of some texts. Understanding a group of texts as a family (genre) of texts is a large part of what helps the learner make sense of such texts.
20) Multimodal Principle: Meaning and knowledge are built up through various modalities (images, texts, symbols, interactions, abstracts design, sound, etc.), not just words.
21) Material Intelligence Principle: Thinking, problem solving, and knowledge are stored in tools, technologies, material objects, and the environment. This frees learners to engage their minds with other things while combining the results of their own thinking with the knowledge stored in these tools, technologies, material objects, and the environment to achieve yet more powerful effects.

22) Intuitive Knowledge Principle: Intuitive or tacit knowledge built up in repeated practice and experiences often in association with an affinity group, counts a great deal and is honoured. Not just verbal and conscious knowledge is rewarded.
23) Subset Principle: Learning even at its start takes place in a simplified subset of the real domain.
24) Incremental Principle: Learning situations are ordered in the early stages so that earlier cases lead to generalizations that are fruitful for later cases. When learners face more complex cases later, the hypothesis space (the number and type of guesses the learner can make) is constrained (guided) by the sorts of fruitful patterns or generalizations the learner has found earlier.
25) Concentrated Sample Principle: The learner sees, especially early on, many more instances of fundamental signs and actions than would be the case in a less controlled sample. Fundamental signs and actions are concentrated in the early stages so that learners get to practice them often and learn them well.
26) Bottom-up Basic Skills Principle: Basic skills are not learned in isolation or out of context; rather, what counts as a basic skill is discovered bottom up by engaging in more and more of the game/domain or game/domains like it. Basic skills are genre elements of a given type of game/domain.
27) Explicit Information On-demand and Just-in-Time Principle: The learner is given explicit information both on demand and just in time, when the learner needs it or just at the point where the information can best be understood and used in practice.
28) Discovery Principle: Overt telling is kept to a well-thought-out minimum, allowing ample opportunity for the learner to experiment and make discoveries.
29) Transfer Principle: Learners are given ample opportunity to practice, and support for transferring what they have learned earlier to later problems, including problems that require adapting and transforming that earlier learning.
30) Cultural Models about the World Principle: Learning is set up in such a way that learners come to think consciously and reflectively about some of their cultural models regarding the world, without denigration of their identities, abilities, or social affiliations, and juxtapose them to new models that may conflict with or otherwise relate to them in various ways.
31) Cultural Models about Learning Principle: Learning is set up in such a way that learners come to think consciously and reflectively about their cultural models of learning and themselves as learners, without denigration of their identities, abilities, or social affiliations, and juxtapose them to new models of learning and themselves as learners.

32) Cultural Models about Semiotic Domains Principle: Learning is set up in such a way that learners come to think consciously and reflectively about their cultural models and about a particular semiotic domain they are learning, without denigration of their identities, abilities, or social affiliations, and juxtapose them to new models about the domain.
33) Distributed Principle: Meaning/knowledge is distributed across the learner, objects, tools, symbols, technologies, and the environment.
34) Dispersed Principle: Meaning/knowledge is dispersed in the sense that the learner shares it with others outside the domain/game, some of whom the learner may rarely or never see face to face.
35) Affinity Group Principle: Learners constitute an "affinity group", that is, a group that is bonded primarily through shared endeavours, goals, and practices and not shared race, gender, nation, ethnicity, or culture.
36) Insider Principle: The learner is an "insider", "teacher", and "producer" (not just a "consumer") able to customize the learning experience and domain/game from the beginning and throughout the experience.

(Gee, 2008, p. 221-227)

APPENDIX B – Epistemic Beliefs Inventory (EBI)

Please indicate your level of agreement or disagreement to the following statements. If you strongly agree, for example, write the number 6 in the blank provided to the left.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
1	2	3	4	5	6

1)_______ Most things worth knowing are not very complicated
2)_______ People should respect the opinions of authorities
3)_______ Really smart students learn things with less effort
4)_______ There are certain truths in life that won't ever change
5)_______ Working on a problem with no quick solution is a waste of time
6)_______ What is true today will be true tomorrow
7)_______ Society needs strong laws to work well
8)_______ When someone in authority tells me what to do, I usually do it
9)_______ Really smart students don't have to work as hard to do well
10)______ Solutions to problems usually come quickly or not at all
11)______ Most important ideas are pretty simple when you get down to it
12)______ Some people are born with more ability than others
13)______ Teachers should focus on facts instead of abstract ideas
14)______ Basic truths exist even though we might not know what they are
15)______ How well you do in school depends on how smart you are
16)______ Too many theories just complicate things
17)______ Things are simpler than most experts would have you believe
18)______ If you don't learn something quickly, you won't ever learn it
19)______ If two people are arguing about something, at least one of them must be wrong
20)______ Children should never question their parents' authority
21)______ If you don't understand a problem right away, going back over it won't help
22)______ People should obey the law
23)______ The moral rules I live by apply to everyone
24)______ Smart people are born that way
25)______ Most of what you learn, you learn during the first try

(Bendixen, et al., 1998)

APPENDIX C – Seven Principles for Educating the Ne(x)t Generation

1. Relinquishing Authority

We know much more than our students do. But they also know much more than we do. When we renounce our own exclusive status as erudite experts, placing our students in the role of teachers and ourselves in the role of students, not only do we model for them the benefits of lifelong learning, but we allow them to experience firsthand what every seasoned teacher already knows: If you really want to master a subject, teach it.

2. Recasting Students as Teachers, Researchers, and Producers of Knowledge

Teaching to the future demands that we imbue students with a sense of intellectual purpose, instill in them a desire to make a difference, provide them with opportunities to reach a wider audience, and furnish them with the tools to break new ground. By recasting students as researchers and teachers, we invite them to participate in what is arguably the most exciting and fulfilling aspect of university life: the production of new knowledge.

3. Promoting Collaborative Relationships

Our socio-cultural landscape is rapidly changing, however. Outside the classroom, through social software such as wikis, chat rooms, and blogs, our students are creating collective knowledge right and left, breaking down traditional boundaries between "me" and "us." Teaching to the future involves harnessing the collaborative impulses already at large in digital culture and directing them toward educational ends.

4. Cultivating Multiple Intelligences

Students and teachers possess at least eight different "intelligences"—spatial, musical, bodily-kinesthetic, naturalistic, interpersonal, intrapersonal, linguistic, and mathematical-analytical—and that no two human beings display an identical intelligence profile. Education for the future needs to address all of these many abilities, teaching students to be aware of and make use of their own particular gifts.

5. Fostering Critical Creativity

Workers of tomorrow will confront issues, problems, and technologies that the teachers of today cannot yet even imagine. To prepare students to "think outside the box" in productive ways, students will need to take the creative risks that enable critical insights.

6. Encouraging Resilience in the Face of Change

Critically creative people regard obstacles as opportunities; they welcome challenges because the act of surmounting impediments so often leads to unanticipated insights.

7. Crafting Assignments That Look Both Forward and Backwards

Double vision is the core attribute of teaching to the future. Tasks require that students continually turn their heads from yesterday (preserve the past) to today (experience the present) and tomorrow (anticipate the future). As teachers, we seek not only to cultivate our students' panoptic vision but also to make them aware of why we are doing so.

(Sword & Leggott, 2007)

APPENDIX D – Interview Questions

1) Describe how you "practice" like a game programmer.

2) Describe how you "think" like a game programmer.

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3) Describe how you "act" like a game programmer.

4) Which features of learning like a game programmer did you like best?

5) Which features of learning like a game programmer did you like least?

APPENDIX E: Letter of Consent and Consent Form

Request for Consent to Participate in an Education Research Project

Research Title Project: Epistemic Learning in the Computer Science Classroom

Researcher: Roman Matwyczuk
Graduate Student, Faculty of Education – University of Manitoba
Teacher – [redacted]
E-mail: roman.matwyczuk[redacted]

Dear Parent(s)/Guardian:

This letter is to inform you of a research project that I will be conducting with my computer science class and invites you to consent to your child's participation in my research project. My research will study the effectiveness of a learning approach where students learn computer science skills and techniques from the point of view of real-world practices by engaging in real-life tasks and problems (i.e., the programming of a computer game). This learning environment allows students to think, act and practice like a computer game programmer while still learning the core skills of computer programming and it is an approach that has become a part of my regular practice.

Your child's involvement in this study is strictly voluntary and participation or lack of participation in the study will in no way impact his or her grades. The instruction in the classroom will be provided to all children regardless of whether or not the results of that instruction are used for my research.

The purpose of my research project is to detail the skills and qualities that students learn as they assume the role of a computer game programmer and to determine if students participating in this process react more favorably to the learning in this manner. This research will help to improve my own practice and provide information to other teachers who are interested in the instructional potential of my approach.

There are no anticipated risks or discomforts related to this research. However, if you feel uncomfortable with any part of this study at any time, you have the right to terminate your child's participation without consequence.

At the beginning and again at the end of the research project, students will be asked to complete a questionnaire that will inform me about their views on learning and knowledge. This questionnaire will help me to determine how best to structure learning activities. As is my usual practice, I will use observations, conversations and samples of students' work samples to assess learning in this environment. Work samples may be used in my final report to demonstrate learning. Students will be interviewed at the conclusion of the study to determine if they found epistemic learning a positive experience. These interviews will be audio-recorded. I will be the only person who reads the surveys and listens to the audio-recordings. The research is expected to take 4 to 6 weeks.

In accordance with the University's standards for ethical research, the identities of students will be protected. Any examples of children's responses and comments used will be anonymous and pseudonyms for the children and the school will be used in the project report. All of my observation notes, collected samples of student work, and classroom information will be kept secure in a locked cabinet at the school. No one other than me will have access to any information that could identify the child. All information that is collected for the study will be destroyed or erased after one year. Furthermore, I will remind you at the end of the term of my intentions to use your child's work for my research. If you decide to withdraw your consent you are free to do so at any time. If permission is not given or is withdrawn, no examples or notes regarding your child will be used in the written report.

A copy of my final report will be available at the school for viewing by interested parties. As well, I would be open to requests to make a presentation to the class, school or parents.

Consent Form

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Your signature on this form indicates that you have read the information provided, that you understand to your satisfaction the details regarding participation in the research project, and that you agree to allow your child to participate in the research project. You are also providing permission for anonymous samples of your child's work samples to be included in the thesis report. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You or your child are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout the participation.

Principal Researcher: **Roman Matwyczuk**[redacted]
roman.matwyczuk[redacted]
U of M Faculty Advisor: **Denis Hlynka,** [redacted]
dhlynka[redacted]

Participant's name: ________________________ Date: __________

Parent/Guardian's: Signature: ________________________ Date: __________

Student's Signature: ________________________ Date: __________

Researcher Signature: ________________________ Date: __________

APPENDIX F: Pea and Kurland's Skill Levels (Modified)

Examine each observable action and indicate whether it is an action that requires a programmer to think, practice and/or act.

Level	Observable action	Epistemic element (Think, Practice, Act)
Program user	Enter **code**	
	Simple code **modification**	
	Execute code	
	Use **quick** keys	
	Use program menus to control **program operation**	
	Integration with other programs	
Code generator	Exercise **precise expression** and/or using logical code blocks	
	Write simple programs following a given **schema** and/or applying library code	
	Learning and/or recalling **formal procedures**, variables, functions	
	Debug for errors	
	Transfer of mental models 3D effects	
	Exercise **situational thinking**	
	Interpret other people's programs	
	Display **originality** in coding programs and/or extending learning beyond taught material	
Program generator	Exercise **adaptive thinking**	
	Apply **heuristics** to problem solving	
	Skill transfer within/between programs/ languages	
	Exercise **persistence** in the face of difficulty	
	Self-assessing code for the purpose of improvement or augmentation	
	Giving **consideration** to solving coding issues through a multiple paths approach	

	Discipline in documenting programs so others can modify it	
	Appreciation for the process of planning and designing a successful program	
	Commitment to meeting the needs of clients (i.e., completing work within deadlines, amending code according to client expectations, accepting critical feedback, etc.)	
Software developer	Making **judgments** using quantifiable sources	
	Respecting **dominant design** principles	
	Enhanced **recognition of domains** beyond programming (i.e., choosing to learn adjunct concepts critical to successful programming)	
	Collaboration in program development and design and contributing to group intelligence	
	Practicing and applying efficient and effective **programming conventions**	

(Pea & Kurland, 1984, p. 152-155)

APPENDIX G: Google Form Document – CSC30S Blitz 3D Forum

This is your classroom's Blitz3D forum that will allow you to share your ideas to help others develop and expand their programs.

My Idea	My Lines	Hints and Suggestions
Inserting a HUD	***score = 0*** ***score = score + 1*** ***Text 100, 100, "Score = " + score***	• **1st line goes before While** • **counter line goes after While within Collision detection control structure (i.e. after the IF)** • **Text line(s) goes just before the FLIP**
Repairing endless loop on sound effects	***chnSfx00=LoadSound("sfx.mp3")***	• **Instead of WAVE, use MP3. Some programs tend to make WAVEs loop in Blitz.**
Downloading .3ds files from the Internet	**http://archive3d.net/**	• **Find the file you want to download** • **Click on the picture and save file** **On other sites:** • **Find the file you want to download** • **Right-click and Save Target As** • **Save the zip file and extract**
Adding 1st/ 3rd person view	**EntityParent(camera,object)**	• **Had to Parent the object and the camera so they move at the same time** • **Have to declare**

		object as a player
Adding Gravity	**TranslateEntity camera,0,-1,0**	• Experiment with the y coordinate for positioning. • Place under While Not KeyDown(1)
Hiding Mouse	**Hidepointer**	• Under While NotKeydown
CameraView-port Mini Map	**PositionEntity cam1, 0, 0, -10 ;cam1, normal view CameraViewport cam1,0,0,GraphicsWidth(),GraphicsHeight() ;cam2, overhead CameraViewport cam2, 0, GraphicsHeight()/4, GraphicsWidth()/4, GraphicsHeight()/4**	• Create two cameras, the first positioned normally and the second looking down on the terrain • Create an object and place it in front of the first camera • Use EntityParent to attach the camera to the object • Move the map window around using PositionEntity
Incorporat-ing a small program into another program	**Include "example.bb"**	• Works best in an If statement, to pinpoint when you want to bring in the external program. • To go back to the initial program, use the include code in the external one.
Rnd or Rand?	**Rand(1,6) Rnd(0.5,0.9)**	• Rand rounds to whole numbers while Rnd allows you to use

		decimals.
Getting rid of the runtime message on a splash sceen	Start() Function Start() Graphics 1024, 768 screen = LoadImage("splash screen.jpg") DrawImage screen, 0, 0 Delay 1000 While Not KeyDown(1) If KeyDown(28) Then Return Wend End Function	• Create a splash screen on Paint, Photoshop, etc. • In your main program, use Include to insert the splash screen program.
Changing Font and Font Size!	; Set global on font variable Global fntArial ; Load fonts to a file handle variables fntArial=LoadFont("Arial",20,False,False,False) While Not Keydown(1) SetFont fntArial Text 15,15,"Insert Text Here!"	• The 20 in the line fntArial=LoadFont("Arial",20,False,False,False) is the font size, so change that number for bigger or smaller fonts.
Mouse Control	mxs# = mxs# + MouseXSpeed() mys# = mys# + MouseYSpeed() If mxs# > 360 Then mxs# = 0 If mxs# < 0 Then mxs# = 360 If mys# > 80 Then mys# = 80 If mys# < -80 Then mys# = -80 RotateEntity camera, mys#, -mxs#, 0 MoveMouse 400, 375	• Under While Not KeyDown(1) Set the coordinates for MoveMouse to the centre of your screen
Camera Range	camera=createCamera() cam_range=10000 While Not KeyDown(1) CameraRange camera,1,cam_range	• This allows you to see further into your space sphere getting rid of the black hole.
Copy Entity	x_sphere = CreateSphere (100) sphere = CopyEntity (x_sphere)	• This lets you copy your sphere, but you first have to make an original sphere

APPENDIX H – Students' ENA Graphs – Stages 1 - 3

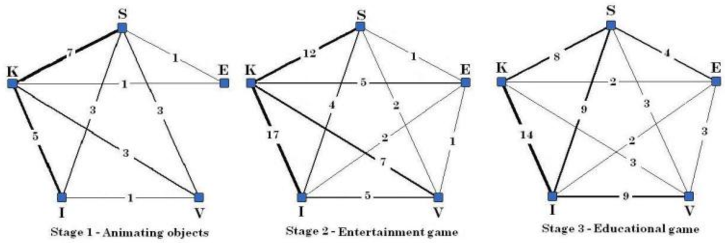

Figure 1 Jordan's ENA graphs

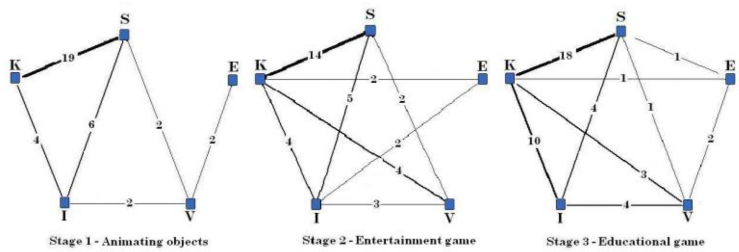

Figure 2 Lorie's ENA graphs

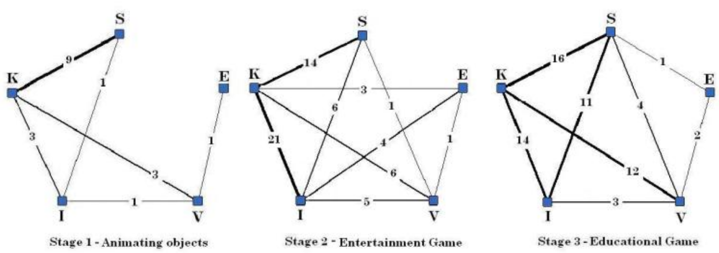

Figure 3 Alex's ENA graphs

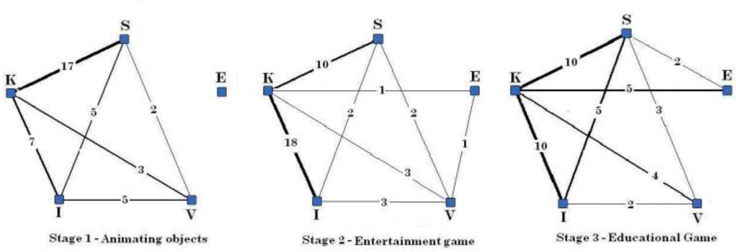

Figure 4 Brook's ENA graphs

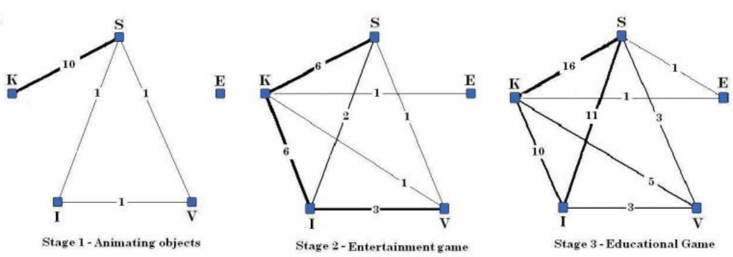

Figure 5 Ashley's ENA graphs