Use of Digital Games in Secondary Science Education: A New Era

Hasnat Jahan[1]
Farah Deeba[2]

Abstract

The advent of technology and digital games has created a completely new dimension in the world of education. While some educationists are concerned about the side effects of involvement of too much technology in education, some mentors are thinking of innovative ideas to utilize the digital phenomenon to engage students and enhance the learning experience. This article explains some of the issues faced by teachers while dealing with a techno-savvy generation and the influence of digital games on children. The article also elaborates the benefits and disadvantages of incorporating digital gaming into basic education. Some of the challenges of incorporating digital games into mainstream education and secondary science education are discussed in detail. The article recommends some tested and innovative methods of incorporating games in secondary science education and suggests some guidelines about planning, choice of games and execution of the procedure.

Key words: digital games, technology, education, secondary science.

Introduction

The "Wikipedia problem" (Richtel, 2012a) which means children turning to internet for readymade answers is the new age phenomenon baffling teachers and educators globally. There are almost equal numbers of teachers who consider technology to be as much a solution as a problem (Richtel, 2012a). While a common belief is that technology is hindering the students' capacity to think and analyze, there is also a strong opinion in favor of the ability of video games and digital gadgets to engage students in learning and enhance their learning by using more than one sensory stimulators (Zyda, 2005). Along with the growing concern about the students' deteriorating attention spans, institutions are incorporating digital games in the process of classroom learning (Richtel, 2012a).

[1] Research Assistant, Faculty of Education, Monash University, hasnat.jahan@monash.edu

[2] PhD student, Faculty of Education, Monash University, fdee1@student.monash.edu

The National Science Education Standards (USA) emphasize that science education needs to give students three kinds of scientific skills and understandings. Students need to learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavor. Students therefore need to be able to devise and carry out investigations that test their ideas, and they need to understand why such investigations are uniquely powerful. Studies show that students are much more likely to understand and retain the concepts that they have learned this way (Olson & Loucks-Horsley, 2000). Hence, it becomes imperative to engage children in science education at an early stage.

Digital games are more capable to gain students' interests and attention than other conventional means of imparting education in a classroom (Richtel, 2012a). However, some teachers when interviewed by Richtel (2012a) also regard them as culprits of exponential decline in the attention span of children. The next sections in this article discuss the involvement of children in games in the technology age, types of games available in the market and the impact of digital gaming as learning aids in classrooms. The article also suggests a systematic process to adopt games as a part of the curriculum and provides some guidelines to effectively incorporate games into basic classroom sessions.

What are Digital Games?

There is no generally agreed definition of games (digital, physical or intellectual) as it may vary with an individual's preference and profession. Salen and Zimmerman (2004) define games as a "system in which players engage in artificial conflict, defined by rules, which result in a quantifiable outcome" (p. 80) .Technology and digitization add new dimensions to games where simulations, interactivity, augmented reality, alternative reality, collective intelligence and sensory stimulators such as sound and visual effects. Digital games are also characterized by their portability and limitless accessibility.

Role-playing games, simulation games and puzzles are some of the most popular digital games. In role-playing games (RPGs), the player enacts the role of a particular character in a virtual world moving from one level to the other based on the outcome of the earlier level. Massive Multiple Online Role-Playing Games (MMORPGs) are an extension of the RPGs where a large number of players interacts in an online virtual world. Simulation games create realistic situations in virtual worlds. The outcome will depend on the player's decision-making and responsiveness and will be closely similar to what may happen in a real world in the same situation. The puzzles genre of digital games involves problem solving and analysis with varying degrees of difficulty depending on the nature of the game.

All types of digital games involve a social involvement of players. Some need collaborative efforts to play while others may be discussed or analyzed socially. In spite of some games being accused of outright violent visual effects, a well-designed game can accelerate the

thinking process by motivating and engaging the participants, encouraging creativity and developing a meta-game (Gee, 2012) i.e., social interactions inspired and enhanced inside or outside the game. Incorporating digital gaming in the basic education framework can lead to augmented competitiveness and multi-dimensional growth in children.

Digital Games in Science Education

Rapid development of information technology in the 21st century requires the mentors and the students to integrate such technology into the curriculum (Shaffer, Squire, Halverson & Gee, 2005). Though the ultimate goal is to benefit the students in terms of learning and experience, unsupervised, unorganized or irrelevant application can lead to complete failure or have negative effects. Some of the negative impacts of digital games in general and in the context of education are listed below:

- Digital games have been facing constant rebuke for allegedly enhancing aggression amongst children and developing a violent streak at an early age. In a study by Anderson and Bushman (2001), children involved in violent video games are more likely to have increased aggressive thoughts, feelings, and behaviors, and decreased social interaction. Use of weapons and being rewarded for being violent in games is a cause of widespread concern.
- Digital games can be addictive for children and make them physically inactive. A long time spent in digital games, in addition to social networking, is considered a cause for reduced physical activity leading to obesity in kids and postural and skeletal disorders (Anderson and Bushman, 2001).
- Addiction to games is also known to make kids socially secluded. Impulsive behavior, depression and increased anxiety levels are largely attributed to excessive gaming amongst children. Some studies also suggest that the children playing games are unable to concentrate and have reduced attention span (Gentile, Swing, Lim&Khoo. 2012).
- Children are prone to absorbing socially unacceptable behavior through some digital games, such as, using profanities and ill-treating females. Lack of adequate knowledge about the material available online is a growing concern amongst the parents (Richtel, 2012b).

Digital games are considered a hindrance to better performance in academics. Students are often found to skip homework to play games. On the other hand, digital games have been shown to help children learn skills, content, and vital "21st-century" skills. From digital games children can learn: content (from rich vocabulary to science to history), skills (from literacy to math to complex problem-solving), creation of artifacts (from videos to software code) and systems thinking (how changing one element affects relationships as a whole) (Thai, Lowenstein, Ching & Rejesky, 2009).

There are other potential benefits of games as learning aid in secondary education. Digital games require strong hand-eye coordination and enhance motor and sensory skills. Sensory stimulation theory proposed by Laird (1985) suggests that effective learning occurs when the senses are stimulated. While some studies show that digital gaming reduces attention span, there are strong evidences of improved concentration for short intervals of time. Digital games involve keeping an eye on every detail, follow the rules and respond proactively to the given situation. Complex digital games help in developing problem-solving and decision-making skills. Some games also involve logical analysis of the situation and pattern recognition and improve memorizing thus assisting in the cognitive process. Cognitive-Gestalt approach by Burns (1995) emphasized the importance of experience, problem solving and developing insights .Playing by the rules teaches children to accept and respect a certain level of discipline.

Multi-player digital games develop a sense of constructive competitive attitude. Collaborative games also improve team-building attitude. They develop time management skills in a team and train the players to cooperate for mutually desired goal. They teach the players to accept defeat as well as strive for better results. Digital games provide an avenue for hyperactive kids to direct the energy in a constructive system based game. They also provide an outlet to release aggression and frustration, thus helping in diffusing stress. Some games also involve physical activity such as Nintendo Wii boxing helping kids to engage themselves mentally and physically through the game. Complex digital games involve high level of multitasking thus improving brain's natural learning process. Brain based learning theory proposes that multi-tasking is an inherent activity of the brain and learning is enhanced by challenges at various levels. Digital games develop efficient situational analysis and strategy making in children. Since games have certain objectives at every level and a final objective, these teach players to devise short term and long-term strategies such as scoring points, retaining energy and reaching the ultimate goal of the game.

James Paul Gee proposes that digital games encourage players to test various hypotheses for a situation and come up with the best possible solution. Hence, digital games become useful while teaching subjects like science that are based on experimentation and testing. Imaginative play is an important part of learning. Simulated environments of digital games provide an opportunity for play, thus becoming an integral part of learning and development (Ke, 2009). Digital games also provide assistance in scaffoldings, i.e., adjusting the level of help in response to the child's level of performance until the individual becomes completely independent. Vygotsky's (1978) Zone of Proximal Development (ZPD) proposes that the children should be assessed on their actual development vis a vis the level of potential development. Digital games follow the same principle where the assistance to the player decreases or the complexity of the game increases as the player graduates from the junior level to the expert level.

Simulation games and the role-playing digital games help players gain expertise or learn by experiencing in a replica of real world situation. In a study of 81 seventh grade students by Akpan and Andre (2000), it was found that the understanding about frog dissection was enhanced with the use of a simulated frog dissection (simulation game) before or after the actual dissection. Experiential learning and action learning theories are based on the premise that individuals learn faster when they experience and actually participate in action.

The discussion above shows that there are ample benefits of digital games when incorporated strategically at the secondary education stage. There are various tested methods of applying digital games in secondary science education in classrooms and innovative methods customized to suit the respective learning objectives., which are discussed below.

Adapting Digital Games in Secondary Science Education

Gee (2012) points out certain characteristics of learning experiences that can help maximize learning outcome.

- Learners have clear goals for taking an action in the experience, an action that they care about. They get a clear feedback for reconsideration and rethinking if necessary to accomplish their goal.
- Learners are actively encouraged to compare and contrast this experience to other related experiences in order to find patterns (generalizations) in experience.
- They are also encouraged to think and discuss about their assumptions and strategies while engaged in a learning activity.
- Learners are encouraged to persist after a failure, explore, take risks, and innovate (and, thus, accepting failure as part of learning.);
- Learners hear and learn language -- sometimes specialist or academic form of language—that fits the experience and the actions and goals that are an integral part of it; and
- Learners are assessed on multiple variables sensitive to growth across time (which can be seen in a "U-shaped" curve, i.e.,it goes up, then down, then up again) and useful for planning new actions and experiences.

These points not only validate the benefits of using digital games but also draw a framework for an ideal digital game that can be used as a learning aid. Science education has largely followed a method of conventional education where facts and information are passed from the mentor to the students who often memorize the concepts and theories. The learning in such a system is highly dependent on the individual's interest in the subject and his capacity to memorize. Since the methodology usually involves reading and sometimes listening, the engagement of the students in the activity cannot be considered very high. However looking

forward in the 21st century, the National Research Council in USA report "Taking Science to School"(Duschl, Schweingruber, & Shouse, 2007) highlights the goal of science learning in four strands. The first strand is focused on integrating the understanding of concept with content knowledge. The second emphasizes the skills and processes for gathering, creating and processing the knowledge. The third strand highlights the importance of understanding the epistemological nature of that knowledge and its development. The fourth strand essentially focuses on students' attitudes, perceptions and habits affecting their participation and engagement in the scientific processes. These strands summarize the phenomenal shift in thought process about science learning from conventional classroom sessions to a multi-dimensional learning experience. Educationists and parents are increasingly concerned about providing relevant education and reforming the educational system to equip the students for a much more technology driven, interconnected and competitive "flat world" (Reimers, 2008; Burke, 2010).

It has been argued that U.S. students' limited science knowledge results partly from a lack of interest in science and motivation to persist in mastering difficult science concepts, and this lack of interest in turn, is related to current approaches to science education (Singer, Hilton & Schweingruber, 2005; Duschl et al. 2007). Genre of digital games can be extremely useful to generate certain level of interest and engage students in the learning process thereby improving their understanding of the theoretical concepts and their practical applications. Imparting science education in informal contexts has some inherent benefits such as customization according to the capacity and voluntary participation of the students. Delacruz (2011) regarded games as tools to support formative assessment and studied the effect of varying level of details about the games rules on learning and performance in mathematics. Her research found that combining elaborated scoring explanation with incentives for accessing game feedback resulted in higher learning gains. The increased motivation brought about by games may have the potential to increase the validity of formative assessments.

Using digital games as an effective learning tool is not a one-step action. On the contrary, it involves a well-researched planning, execution and review.

Planning as a process starts from choosing the right type of game. The games that are chosen should be compatible with the available infrastructure, hardware/software and resources. For example, consideration has to be given to amount of memory needed to store and execute the game, availability of graphic card, devices needed for the game such as joystick or mouse and availability of internet to download the games or intranet to distribute them over the internal network. Choice of games should adhere to the socially acceptable norms and should not fall under any category that is prohibited or harmful for the target audience.

Ratings such as the such as the Entertainment Software Ratings Board (ESRB, 2012) and the Pan European Game Information (PEGI, 2012) can be helpful for teachers. These tools rate

the games on the basis of their contents and appropriateness for different age groups and help teachers to decide suitability of the game for the target students and ensure that the games are not too difficult for the kids' level of understanding. Certain supporting factors such as language and time need to play the game module should be considered (Squire and Jenkins, 2003). The mentors or the teachers also need to be trained for carrying out the process. Teachers need to be trained professionally and on methods of engaging the students to derive maximum benefit or learning outcome as in this case, from the curriculum (Deeba, 2012). Some commercially available educational games with their respective learning benefits are listed in Table 1.

Table 1. Some Popular Commercial Games and Their Learning Benefits

Game	Learning Benefits/Learning Areas
Age of Empires II	History, strategy and resource management
Bioscopia	Zoology, cellular biology, human biology, botany and genetics
Chemicus	Chemistry
Immune Attack	Understand how immune system works
DoomeD	Learn about Science
Roller Coaster Tycoon 3	Management, kinetic and potential energy
Chemsense	helps students to explore chemical processes and see the effects of changes
Foldit	teach the concept of protein folding
Machinarium	electricity and forces

Source: Dr Felicia, P. (2009). *Digital Games in Schools. A Handbook for Teachers.* Brussels, Belgium: European Schoolnet

Once the appropriate games are chosen, the actual execution is carried out by effectively incorporating the games into the curriculum. The teacher plays a vital role at this stage. Students need to be debriefed about the subject to create a theoretical foundation. Debriefing is also important to make a connection between the game and the curriculum (Felicia, 2009, p. 29). While one game may be used to address a set of students, it is important to closely monitor the participation of every individual.

It is extremely critical to evaluate the outcomes to gauge the effectiveness of the game on the target audience. The game result should be easily identifiable and comparable to understand that the learning objectives were achieved. In games related to math, for example the games involving counting or making simple calculations, the students should be able to recall the numbers or should be able to make calculation and reach a result. A group discussion or a dialogue with every individual can give a fair judgment about the learning outcomes using games.

Gap between Ideas and Reality

There is no dearth of innovative ideas for the use of digital games in education. However, there are certain challenging ground realities when it comes to actually adapting or incorporating gaming into secondary science education. Though digital technology is being used in many aspects of administration of educational institutions, the pedagogic benefits of e- learning remain unexploited due to perceived difficulties in adapting and engaging educational environment (Fladen & Balshki, 2005). Financial aspects, time involved in training and unwillingness to accept change can be some of the factors causing resistance to adapting gaming as a part of the curriculum. Financial considerations are one of the major hindrances to digital gaming in secondary education. "Digital divide" is the term that emerged in 1990s to describe the gap between technology "haves" and "have-nots" (Richtel, 2012b). This divide narrowed due to commercial affordability of technology and peer pressure to acquire the latest.

Bridging the Gap

Proponents claim that games have the best pedagogy in them and prepare students for 21st century careers, while detractors are concerned about the aggressive and dangerous behaviors of the users. Despite their differences, both the sides agree that learning is possible from games (Khine, 2011). The time has come for accepting the importance of technology-facilitated learning as the most important change in today's education system.((Shaffer, Squire, Halverson & Gee, 2005). It is imperative to broaden the horizons and enhance intellectual capabilities of learners, which can be achieved by using constructive digital games.

Conclusion

Society is undergoing tremendous change in respect of development of technology and skills. Conventional education system is being challenged to prepare the new generation for the age of super specialization. There is a demand to bring about a major change in the methods of imparting education especially in the early age. Educational digital games are being accepted globally to improve the quality of education because of the innate characteristics of games such as motivation, engagement, adaptability, simulation, collaboration, and data collection (McClarty, Orr, Frey, Dolan, Vassileva & McVay, 2012). Violence associated with the digital games is a factor that needs to be handled with caution. The cause and effect relationship of violence and gaming can be attributed to the classical conditioning that uses rewards for favorable behavior such as scoring points for killing or shooting in digital games. The issue needs to be addressed with an aim to making educational games non-violent, attractive and engaging as all other media of entertainment. With the benefits of digital games being identified and accepted across the world, wider use of augmented reality and game-based learning is expected in the coming years (Johnson, Smith, Willis, Levine, & Haywood, 2011). Entry into teaching of new teachers who may have grown up with digital games experience themselves is likely to hasten this process.

References

- Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive effect, physiological arousal and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological Science.* 12(5).
- Akpan, J. P., & Andre, T. (2000). Using a computer simulation before dissection to help students learn anatomy. *Journal of Computers in Mathematics and Science Teaching, 19 (3),* 297-313.
- Burke, A. (2010). Teacher as leader in a "flat world": Preparing students in a global community, *Language Arts Journal of Michigan, 25(2),* Article 4.
- Burns, R. (1995) *The Adult learner at work,* Sydney: Business and Professional Publishing Centers for Disease Control and Prevention, (2010). State Indicator Report on Physical Activity, 2010.*National Action Guide. Atlanta:* Ceenters for Disease Control and Prevention.
- Deeba, F. (2012).Use of digital games to address the decline of Students' participation in science. A*cademic Research International. 3*(2). Victoria, Australia.
- Delacruz, G. C. (2011). Games as formative assessment environments: Examining the impact of explanations of scoring and incentives on math learning, game performance, and help seeking. *CRESST Report 796.* Los Angeles, CA: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).
- Felicia, P. (2009). *Digital Games in Schools. A Handbook for Teachers.* Brussels, Belgium: European Schoolnet.
- Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). *Taking science to school: Learning and teaching science in grades K-8.* Washington, D.C.: The National Academics Press.
- ESRB, (2012). ESRB Ratings Guide. Retrieved from http://www.esrb.org/ratings/ratings_guide. jsp
- Fladen, E., & Blashki, K. (2005). Learning = playing: Interactive learning and game-basedd esign principles. Paper presented at the 22ndAcsiliteAnnual Conference, Brisbane, Australia.
- Gee, J.P.(2012). Can Technology-Rich Learning Close the Participation Gap? Message posted to http://www.jamespaulgee.com/. 18 December, 2012.
- Gee, J.P. (2012)Big "G" Games. Message posted to http://www.jamespaulgee.com/,10 December, 2012.
- Gee, J. P., & Shaffer, D. W. (2010). Looking where the light is bad: Video games and the future of assessment. *Epistemic Games Group Working Paper 2010(02)*. Madison: University of Wisconsin-Madison.
- Gentile,A.D., Swing L.E., Lim G.C. &Khoo, A. (2012). Video Game Playing, Attention Problems, and Impulsiveness: Evidence of Bidirectional Causality. *Psychology of Popular Media Culture. 2012, 1(1), 62–70.*
- Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *The 2011 Horizon Report*. Austin, Texas: The New Media Consortium.
- Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. *Handbook of Research on Effective Electronic Gaming in Education.* New York: IGI Global.
- Khine, S.M.(2011). *Learning to Play.* New York: Peter Lang Publishing

- Laird, D. (1985). *Approaches to training and development Reading.* Massachusetts: Addison-Wesley.
- McClarty L.K., Orr A., Frey M.F., Dolan P.R., Vassileva V. & McVay A (2012) .A L i t e r a t u r e Review of Gaming in Education Research Report.
- Olson, S., & Loucks-Horsley, S. (2000). Inquiry and the National Science Education Standards: A Guide for Teaching and Learning [Electronic Version]. Washington, DC: National Academy Press. Retrieved from http://www.nap.edu/catalog/9596.html
- PEGI, (2012). Official Website. Retrieved from http://www.pegi.info/en/index/id/24
- Reimers, F. M. (2008). Preparing students for the flat world. Education Week. Retrieved f r o m http://www.edweek.org/ew/articles/2008/10/08/07reimers.h28.html
- Ritchel, M. (2012a, November 1). Technology Changing How Students Learn, Teachers Say.T h e New York Times. Retrieved from http://www.nytimes.com/2012/11/01/education technology-is-changing-how-students-learn-teachers-say.html?pagewanted=all
- Ritchel, M. (2012b, May 29). Wasting Time Is New Divide in Digital Era. *The New York T i m e s .* Retrieved from http://www.nytimes.com/2012/05/30/us/new-digital-divide-seen-in-wasting-time-online.html?pagewanted=1
- Shaffer D., Squire K, Halverson R., Gee J. (2005) *Video Games and the Future of Learning*. Phi Delta Kappan, 87 (02) .
- Singer, S.R. Hilton, M.L. and Schweingruber, H.A..(2005). America's lab report: Investigations in high school science. *Committee on High School Science Laboratories: Role and Vision.* Washington, DC: The National Academies Press.
- Squire, K. and Jenkins, H. (2003). *Harnessing the power of Games in Education 3*(5). Institute for the Advancement of Emerging Technology in Education (IAETE)
- Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals.* Cambridge, M A : MIT Press.
- Thai, A., Lowenstein, D., Ching, D., & Rejeski, D. (2009). Game Changer: Investing In D i g i t a l Play to Advance Children's Learning and Health. New York: The Joan Ganz Cooney Centered Sesame Workshop..
- Vygotsky, L.S. (1978). *Mind and society: The development of higher psychological p r o c e s s e s .* Cambridge, MA: Harvard University Press.
- Zyda, Michael. (2005). From Visual Simulation to Virtual Reality to Games. *IEEE Computer Society.0018-9162/05.*