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What is serious about a serious educational game?

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Today's millennial generation or the "gamer generation"[*] is immersed in technology and digital innovation that is changing the way we teach and learn. This includes the use of videogames and what are called "serious educational games" (SEGs). The goal of SEGs is to improve knowledge and skill. SEGs are part of the multi-billion dollar digital game industry encompassing mobile, PC and tablet applications designed for military, government, business, education, healthcare, and professional training applications.

As early as 2013, Nolan Bushnell, founder of Atari, Inc. predicted there would be a massive change in the educational arena with the introduction of digital games. He foresaw the impressive reliance on digital games as formidable learning tools, their ability to accommodate learning styles, simulate real-world complexity, and promote complex decision-making and problem-solving skills.

Given the now apparent heavy reliance on digital games for learning, does this mean the classroom blackboard will be replaced with the tablet? Will students abandon their Texas Instrument calculators for game consoles? As we witness the transformation of learning[†] with educational games, we need to ask whether the evidence supports their rapid adoption and whether the effects of digital games are as positive (and long lasting) as acclaimed.

Three key considerations come to mind as we address the value of the digital education movement. First, what makes digital games "serious" and how do they differ from console-based videogames? Cheng and Annetta[1] suggested that serious games provide "authentic learning experiences" whereas videogames only involve imaginative (fantasy

* The term Millennial generation was first coined by 'Howe and Strauss (1991). Tapscott (1998) coined the term "Net Generation." The terms 'digital native' and digital immigrant' was coined by Presnky (2001) and the term "IM Generation" was coined by Lenhart, Rainie, and Lewis (2001).

† This topic is thoughtfully covered in a book by Maloy et al. (2013) called *Transforming learning with new technologies*.

interfaces) and superficial play‡. In this respect, SEGs contain an intrinsic motivational property. Game rules and actions foster learning through pedagogy whereas videogames (VGs) only lead to superficial learning designed around play skill[2]. In addition to engaging users for a defined purpose (goals), SEGs also help users overcome a problem or eliminate deficiencies. This stands in contrast to VGs that focus more on the 'rich experience' of the user and maintaining their interest in play for fun alone.

A second consideration is do they work? In other words, have studies shown that SEGs improve learning (knowledge and skill acquisition), reduce negative behaviors, advance health promotion goals, or achieve favorable outcomes where intended? For this we can turn to several meta-analyses and systematic reviews that synthesize the performance of SEGs as learning instruments.

Third, what criteria are used to evaluate these games; does the industry rely on scientifically valid benchmarks?§ In other words, what is it about game mechanics (i.e., rules of play) that facilitates learning in ways that either mimics the didactic methods we encounter in the traditional classroom or that augments teachers' instructional capabilities?

What the Experts Say. Baranowski and colleagues[3] defined a VG as "any game played on a digital device and encompasses a wide range of games played at arcades, over the Internet on personal computers, or on dedicated game consoles …" Simply stated, VGs are a form of entertainment that involve a game, and are qualified by play, interactivity, and a narrative, but may or may not have learning value.

DeSmet and colleagues[4] suggested that "serious games differ from mere entertainment games in their aim to educate or promote behavior change." Along these same lines, Ke suggested that "learning games" provide structured and immersive problem-solving experiences that enable the development of both knowledge and "ways of knowing" to be transferred to the situations outside of the original context of gaming or learning[5]. Serious games have "epistemic value" and may involve puzzle solving (spatial cues), exploration and memory retention, strategic planning, decision-making, and social interaction in novel or simulated settings (i.e., collaboration and negotiation). In all of these cases, repetitive drill-and-practice type games certainly enable learning.

In his now classic book "*What video games have to teach us about learning and literacy*" James Paul Gee argued that all games (video and serious) contain potential "learning" value because the user is pressed to figure out the design grammars or production rules that make the game challenging. Videogames (first-person shooter game, real-time strategy games, or simulation games) are all examples of multimodal literacy and through "stealth learning" users acquire a sense of the game's internal logic (i.e., design grammars outlining what is and what is not possible in the game play). This contributes to engagement and continued play but also produces a form of knowledge[6]. Gee talks about "semiotic domains" as collections of signs, symbols, and representations, however, they teach people how to think and act. This knowledge can be social by nature (negotiating social interactions between the player and non-playing characters) or based on skills acquired during exposure to the game. Regardless, Gee felt that learning even in stealth format (exercising learning muscles without knowing it), should be considered a fundamental part of every digital game.

Marsh[7] wrote that "serious games are digital games, simulations, virtual environments and mixed reality-media that provide opportunities to engage in activities through responsive narrative/story, gameplay or encounters to inform, influence, for well-being, and/or experience to convey meaning" (p. 63). Unfortunately, this definition bears little on the role of SEGs in education or even hints of the learning component that makes a game have educational value.

Distinguishing Features. There are other factors that distinguish SEGs from VGs. When utilizing SEGs, youths author their own

experience. In other words, they choose their own pace, stop the game and return to earlier steps, and in many cases seek support from the game to master certain elements before they move on. This latter form of guided 'scaffolding' or in-game learning support is not available in a VG, which unfolds regardless of user inputs. SEGs can also be personalized using learner supports including pop-up notifications that give advice or help with additional narration that can be tied to performance, all features that improve learning and are not available in VGs[8].

Several other features of SEGs may create a basis for distinction including the focus on mastery, autonomy, and the challenge within the SEG that does not appear in VGs. Early learning theorists highlighted the need for "challenge, fantasy, and curiosity" as requisite parts of intrinsic motivation for learning[9]. Children or youth playing SEGs are given game rules that challenge them to acquire new skills; they must master these skills to some level of proficiency in order to advance in the game. VGs, on the other hand, do not have intrinsic challenges and are utilized more passively, unless a game console is used to manipulate scenes in the game. However, other than dexterity and hand-eye coordination, there is no direct "knowledge' gained from exposure nor any anticipated change to intrinsic motivational factors that comes with repeated exposure.

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‡ Piaget (1962) has written the classic opus on the role of play in child development.

§ A related concern is which features of the digital game is related to engagement and supportive of learning. While certainly a valid concern, it is far beyond the scope of this **eNEWS** to explore in detail this pressing question.

Assessing Efficacy of SEGs. The second question addresses the issue of what criteria are being used to evaluate SEGs and demonstrate their effect on learning? Here we encounter a wide swath of endpoints depending on the focus. Some researchers examine visual perceptual benefits, task switching capabilities, selective attentional processes, implicit learning and speed of processing. Other game studies focus on fluid intelligence tasks including problem-solving skills, analogical reasoning, memory and executive functions**. This latter focus can be called meta-cognition and there is evidence that SEGs do improve meta-cognitive functions[10].

Studies of learning in classroom situations readily support the value of engagement and motivation for achievement[11-12]. Part of the premise for this linkage is that students paying attention and motivated to acquire new skills or knowledge will "learn more" and retain this information for later recall. The same should hold for SEGs as long as the student is engaged in the game and motivated to play[13-14]. This is perhaps why so many studies of SEGs focus on immersion or presence and the ability of the game to induce a state of "flow" marked by deep concentration and enjoyment[15-16].

Reviews of game design and learning have not been entirely supportive of this claim[17]. For instance, Boyle et al.[18] updated an earlier literature review by Connolly and colleagues[19] who had examined the efficacy of SEGs and games through 2014 and reported that evidence for the efficacy of 'games for learning' and serious games was inconclusive. This stands in contrast to findings based on studies of game-based learning emphasizing acquisition of domain-specific knowledge (i.e., science, mathematics, and engineering). For instance, Sedig[20] showed that middle school youth could both enjoy and learn geometry using a SEG format. Spires et al.[21] showed that middle school youths could learn hypothesis formulation in a science problem-solving task framed by a digital game mystery narrative (discover the virus or disease pathogen).

SEGs and Health Promotion. Studies of health-related SEGs complicates the scenery. This is because the "targets" that exemplify "learning" are so different from the traditional STEM outcomes. For instance, evidence is accumulating that several health-related games that target youth with asthma, diabetes, medication adherence and treatment compliance, and even those focused on nutrition and exercise produce change in knowledge, attitudes and behavior[3,22]. In these cases, the definition of learning has to be flexible and consistent with the program goals of effecting health-related behavior change. Examples of valid endpoints include reductions in hospitalization, change in diet and physical activity (increased consumption of fruits and vegetables), fewer ER or urgent care visits, use of inhalers for asthmatics, and for psychosocial (cognitive) measures greater confidence (i.e., self-efficacy), self-management, knowledge of disease characteristics, and health locus of control (for chronically ill children).

Two studies in particular shed some light on the role of digital games in promoting health. First, a meta-analysis by DeSmet and colleagues[4] canvassing 54 qualifying studies showed small positive effects on healthy lifestyles (behavior) with knowledge showing the largest change. No long-term effects were obtained for behavior and effects on clinical outcomes (i.e., depression) were relatively small.

Second, a systematic review by Johnson and colleagues[23] also showed small effects across 19 health promotion studies; with effects strongest for health behaviors and smaller for cognitive outcomes. Both sets of findings should not deter continued research on the efficacy of digital learning games, because these reviews comport with findings from studies that use non-digital approaches as well. For one thing, it is hard to change intransigent behaviors and it is even more difficult to sustain these changes (e.g., weight loss in obese individuals). The target of most of these programs is motivational and there is considerable evidence reinforcing how hard it is to change a person's motivational state††.

Caveats & Considerations. Missing from these studies is elaboration of the precise mechanism(s) that leads to behavior change. Many of the game design grammars are tied to social cognitive and social learning theory or the health belief model; some rely on the transtheoretical model of change, self-determination theory or even reasoned action theories like the theory of planned behavior. Regardless of theoretical backdrop, what is not examined closely is how the game narrative (story) and the game dynamics (game mechanics or rules) influence adoption of new behaviors (i.e. the "black box" mechanisms).

Strengthening the theoretical foundations of game design requires elucidation of the syntax, axioms, and postulates encompassed by the game mechanics. For example, is behavior changed through emotion-evoked responses that arise from engaging the game, or emotions lead to increased attention to the game story and retention of the material in a sensitized state? When this occurs, do emotions lead to elicitation or inhibition of behavior? The fact that a child is "immersed" in a game, enjoying the story narrative and identifying with the main protagonist, does not ensure that their behavior will change, particularly if it means taking a medication that makes them feel sick (i.e., treating cancer). This is perhaps what prompted Ke to write that the "account of what, how, where, and when domain-specific learning is integrated into gameplay during the game design process remains murky" (p. 220)[5].

One possible route to find out answers to these questions is to include in the game play periodic user learning assessments that ask specific questions about the level of "identification" with primary characters, what

** There are also studies that examine the effect of active videogames or "exergames" on physical functioning including balance, nutrition, and exercise as well as studies of game experience on affect, arousal, and neural activity.

†† Several additional meta-analysis papers reinforce these findings including one by Sitzmann (2011) and one by Wouters et al. (2013).

expectations the individual has about various outcomes (will the protagonist increase fruit and vegetable intake?), and whether the player feels attached to the protagonist or self-identifies with an avatar (i.e., *emoting by proxy*)[24]. This has become the mantra of several instructional technology experts that have investigated "game user experience."[25]

Game-Based Learning. Ke[5] strikes a chord between the gamer mode and the learning mode, the former representing just playing but not learning and the latter representing playing while learning (or learning while playing) from the core game mechanics. When players "play to learn" they become involved conceptually through interactions that build knowledge, exercising hypothetico-deductive reasoning, and through the context by being immersed in the narrative, game characters and role-plays they learn content. Learning occurs in a myriad of ways depending on the content (the narrative transports the learner), but includes memorization (memory retrieval procedures), understanding (identify rules), application (solving a problem), analysis (breakdown and differentiate), evaluation (compare and contrast), and creation (translate to a new setting). Through activity and enactment with other people the learner constructs the world, solves the problem, and gains (situated) meaning. This route involves sharing tasks, using game tools, and producing knowledge through social relationships. A third component involves offloading working memory demands and building cognitive schemata that become automated with time. This allows the user to "learn" while efficiently building long-term repositories of knowledge (i.e., *the cycle of expertise*). Problem-solving worksheets and guided scaffolds are instrumental toward this goal.

Concerns about Research Methods. There are several methodological concerns with studies that examine SEGs. Boyle and colleagues[18] point out that the randomized controlled trial (RCT) is not the main choice for evaluating the efficacy of many games. Indeed, of 143 game publications they reviewed, only 18 used the RCT design whereas 72 used a quasi-experimental design. RCTs go a long way to ruling out confounding and also provide a stronger foundation to make causal inferences. In other words, preexisting differences, like gaming experience, SES, or anything that might be related to the outcome (access to computers), is equally distributed between conditions.[‡‡]

Girard et al.[17] point out that another major concern is the lack of effective control groups in efficacy trials for SEGs and VGs. Consider that control groups could consist of a no training condition, or a condition exposed to normal classroom instructional methods with a teacher or even an innocuous game that avoids teaching the same core curriculum (with the same active ingredients) to control for time on task in a computer-mediated environment.

The lack of a clear-cut comparison group when evaluating technology-based instruction raises the question what is being tested? Is it the interactivity of an SEG or is the content of the game in addition to the instructional modality? Which design feature creates the biggest effect and why? SEGs appeal to different sensory and 'implicit' memory processes compared to face-to-face teaching because of the former's heavy reliance on graphical representation[§§]. In addition, some SEGs use avatars, and this raises concern that social identification and vicarious learning processes are at work that may not exist or be replicated in the classroom.

Another overriding concern regards the persistence of effects following exposure to a SEG. If a student is given the opportunity to learn a new skill or acquire new knowledge regarding science, for example, do the effects of the SEG persist through the school year? Very few studies of SEGs have addressed this issue, so we don't know if the knowledge learned was transferred to long-term storage and became accessible for future use. Most rigorous evaluations of SEGs use a short time frame to assess persistent effects, with posttests ranging anywhere from a few days to a few weeks. Examination of these "durable effects" using a much more extended time frame would go a long way toward clarifying the pedagogical value of SEGs and more clearly distinguish them from VGs.

Summary. Digital games are fun, as many game players will attest. Learning biology or geometry is not always fun, as many school children will attest. However, if we make learning biology, geometry or history "fun" we can improve learning in the context of "serious educational games." We can also teach young children how to navigate social relationships without resorting to aggression or bullying, and we can educate young minds to the pitfalls of drug use. We can also teach chronically ill children alternative ways to build self-esteem and develop self-management and coping skills that help them deal with the psychological brunt of their health issues.

These examples, representing only a handful of the thousands of opportunities that await our attention, represent the future of serious educational games. Digital games are technological "learning tools" and rather than impose learning theory on game design, it may be prudent to shift the paradigm to include a new field of educational game design that incorporates instructional principles. This means blending learning theory with educational research to improve game design.

This paradigm shift will help address the "*what, how, where, and when*" Ke suggested was so crucial to understand how serious educational games work. In this way, game designers can create situated learning environments that speak to a child's curiosity, intrinsic motivation, and social needs. At the same time, they can also address the child's motivation to demonstrate competencies while engaged in play. This approach should speak to the digital natives and Net Generation who, in light of the limited attraction of traditional instructional

‡‡ Rubin (1974) has written about the stable unit treatment value assumption (SUTVA) as a requirement for RCTs and for making causal inference. Brown and Liao (1999) highlight the importance of RCTs in prevention studies and the associated rigor with this design for internal validity and producing unbiased estimates of the treatment.

§§ There is considerable research on the role of gaming and activated brain processes that should also be considered, see for example, Bailey and West (2013).

methods (drill and kill), strive for alternative and engaging forms of learning.

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