**Designing educational technology: Getting the mix right between theory and practice**

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**Introduction**

Designing effective educational software is not an easy feat when taking into consideration of the main theories that underpin the educational process, with this paper seeks to explore this process as a medium for reflection on game development. This paper consists of three parts, first essential background theories surrounding learning and motivation need to be discussed, also games and gamification need to be defined in order to understand the approach taken to create an educational software. The second aspect of this paper outlines a potential design concept for an educational piece of software which aims to increase engagement in both physical education and science, followed with a justification of the main outcomes. The last aspect of this paper involves a critique of the design as a process for reflection on the development process and end product.

**Educational issue**

The creation of Alchemy! serves to address two key issues plaguing Australian secondary education, disengagement with science as an academic pursuit and falling participation rates in physical activity in physical education classes. First of all disengagement in science has been a significant concern within secondary education for the past decade (Buccheri , Gürber & Brühwiler, 2011, Cavanagh 2005, Cox, Leder & Forgasz 2004, Craig 2005, Hsiao , Chen & Huang, 2012) Physical activity participation rates drop off in middle adolescence due to students lacking class time self-exploration and meaning making through movement (Brown 2008, Kirk, 2006 & Kinchin, 2001)

**Learning theories**

Harasim (2012), Kapp (2012) and McInerney & McInerney (2010) suggest that a significant theory in behaviourism is Skinner’s theory of operant conditioning; which focuses on voluntary behaviours rather than involuntary reflexes (See Pavlov’s theory of classical conditioning) Harasim (2012) and Kapp (2012) suggest operant conditioning involves an independent animal which manipulates a lever releasing a reward if certain conditions are met; this construction is most commonly known as “Skinners box”. However this concept can be extended into the study of gamer behaviour as individuals methodically collect ‘experience points’ to advance their character’s level a game.

Another key theory towards motivation is the Socio-cognitive view, Harasim (2012) and McInerney & McInerney (2010) suggest that the socio-cognitive view focuses on intrinsic motivation or the internal drive to learn via the student observing and imitating the actions of role models. This is heavily reliant on the interests of the learner, which can be classified into two categories, situational and personal. *Situational interest* which is commonly short term relies on the methods the educator conveys the intended message. An example of this showing a documentary on the destruction of the environment and shaping a progression of lessons to support this, which may ‘plant the seed’ to develop into a personal interest. *Personal interest* can be viewed as a long term desire to understand an idea or topic that is maintained by an internal motivator. Personal interests are vastly influenced by experiences that have occurred earlier in life, such as cultural practices, emotions associated with the activity and how relevant the activities are to our goals in life. However motivations are not enough to constitute learning experiences, especially when students are learning through experience.

Kolb (1984) proposes that experiential learning has 6 characteristics; learning is best conceived as a process, not in terms of outcomes, learning is a continuous process grounded in experience, learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world (learning is by its very nature full of tension), learning is a holistic process of adaptation to the world, learning involves transactions between the person and the environment, learning is the process of creating knowledge that is the result of the transaction between social knowledge and personal knowledge. This view on the process of education underpins the core model in experiential learning, that being Kolb’s (1984) Model of Experiential Education;

Kiili (2005) adapts Kolb’s (1975) experiential learning model to create the experiential gaming model, which consists of an ‘ideation’ loop (an expanded conceptualization stage) and an experience loop (simular to Kolb’s model). Killi (2005) also suggests that the experiential gaming model operates like the human circulatory system, with the heart (Challenges) ‘pumping’ problems through the player to sustain motivation and engagement which prompts the generation of solutions through the ‘ideation’ loop and skill development through the experiential loop.



It is still not enough to merely consider what motivates individuals and how the experiences should be structured to promote learning, the debate of if knowledge is better acquired or learnt needs to be focused on; Gee (1991) discusses the difference between acquisition and learning, which are often used interchangeably;

* Acquisition ‘is a process of trial and error... it happens in natural settings which are meaningful and functional in the sense that the acquirers know they need to acquire something in order to function and they want to so function
* Learning ‘is a process which...involves explanation and analysis, breaking down the thing to be learned in analytical parts, it involves attaining along with the mater being taught, some degree of meta-knowledge about the matter

This highlights the complex nature of learning theories and the development of knowledge in educational constructs, so in summary games need both external rewards (operant conditioning) and internal rewards (socio-cognitive view), a system in which students grow and develop their experiences (experiential learning and experiential gaming model) and developing knowledge (acquisition vs. learning) in order to be effective.

**Defining Games**

Kapp (2012) eventually suggesting that the elements of system, players, abstract, challenge, rules, quantifiable outcomes, interactivity, emotional reaction and feedback converge to “make an event larger than the individual elements” (pp.9). Juul (2005) takes a different stance on defining games by suggesting “A game is a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels emotionally attached to the outcome and the consequences of the activity are negotiable” (pp.36). Gee (2009) argues good digital games consist of six key properties, an underlying rule system and game goal to which the player is emotionally attached, micro-control that creates a sense of intimacy and power, experiences that offer good learning opportunities; a match between affordance and affectivity, modelling to make learning from experience more general and abstract, and encouragement to players to enact their own unique trajectory through the game (p. 78).

Drawing these four differing views on what constitutes a game suggests that ‘a game is a system of rules, rules which mediate interactive and abstract environments by issuing challenges, prompting emotional reactions from the players as they work towards a quantifiable outcome. This outcome can only be achieved through scaffolding and on demand feedback loops which are freely entered and experiential in nature. This definition may seek to classify games, but it falls short of detailing what is meant by games as a system and the influence and importance of challenge in learning.

Salen & Zimmerman (2004) suggest that systems are “A set of things that affect each other within an environment to form a larger pattern which is different from any of the individual parts” (pp51), Kapp (2012) aims to progress this idea further, suggesting that a system is “a set of interconnected elements occur within the “space” of the game”(pp.7), Challenge is an essential aspect of any game, as players need to be motivated in order to engage within the frame of the game. However the degree of challenge posed must be progressive as the participant gains skill or the individual may enter a state of boredom or anxiety, this process forms what Arnold (1979) argues as “peak experiences” and Csikszentmihalyi (1975) and Kapp (2012) claims as the “flow continuum”.

**The Flow continuum or peak experiences?**

Flow or peak experiences, During optimal experience, a person is in a psychological state where he or she is so involved with the goal driven activity that nothing else seems to matter (Kiili, 2005) on the condition that the individual is not in state of anxiety (over stimulation) or boredom (under stimulation) (Kapp, 2012). However this state is not just limited to gaming, as studies of physical education also have their own phenomenon model of this state (Brown, 2008) as shown below;

|  |  |
| --- | --- |
| Arnold (1979) | Csikszentmihalyi (1975) |
| Uniqueness  | Challenge-skill balance |
| Transience of self  | Merging of action and awareness |
| Euphoria in perfection  | Immediate and unambiguous feedback |
| Total immersion  | Concentration on the task at hand |
| Control  | Paradox of control |
| Loss of fear  | Loss of self-consciousness |
| Effortlessness | Transformation of time |
|  | Autotelic (internally motivated) experience |

The difference between these two theories is that both Arnold (1979) and Csikszentmihalyi (1975) agree that the individual needs a sense of control and to be immersed and transcendent of themselves; however Arnold (1979) fails to recognise that challenge has to be balanced with skill, instead claiming that the activity needs to be effortless and the participant becomes euphoric in perfection, Arnold (1979) also does not list motivations as a contributing factor peak experiences, where Csikszentmihalyi (1975) suggests that the participant must be internally motivated whist engaging in the task.

Both models suggest that anxiety and fear are the bane of this heightened state, however Comfort Zone model (Brown, 2008, which is widely accepted to be the model for learning and engagement in Outdoor education) suggest that a level of fear/anxiety is constructive to the learning process otherwise the individual risks either not developing their skills or discontinuing the activity. The comfort zone model is structured with the individual’s zone of comfort situated in the centre surrounded by the ‘panic zone’. The individual moves further from their comfort zone through the panic zone as they experience greater levels of stress or challenge. The risk is that the risk of the individual regressing back into their comfort zone and suffering from an adverse learning experience increases if an individual experiences too much stress or challenge; meaning that the educator needs to control the levels of risk to their students. However the model is not an exclusive dualism as there is an area of overlap between the two zones which can be known as the challenge zone, and this is where personal growth and the development occurs, in an environment of controlled fear and stress. (Brown, 2008)

The comfort zone model resonates with aspects of Vygotsky’s (1962) Zone of Proximal Development model (Harasim, 2012), which highlights an individual’s current level of performance and the zone for future growth if facilitated by a teacher or more capable peer but falls short of suggesting a state of over stimulation. However regardless of the theory chosen to highlight the optimal state of stimulation Shernoff, Csikszentmihalyi, Schneider, & Elisa (2003) points out that the state of flow is conductive to the learning process and a controlled level of stress greater than what the individual is accustomed to can be conductive to the learning process (Brown, 2008).

**Gamification**

Kapp (2012) proposes that “gamification is using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning and solve problems. (pp.10)”, However Llagostera (2012) suggests that gamification is normally viewed as the addition of badges and leader board to induce an element of ‘playfulness’ to the learning experience. This suggests that gamification is the deconstruction of a game’s reward structure and applying the concepts into reality. However Kapp (2012) insists that gamification is not the addition of badges, rewards and rewards, trivialisation of learning, new (Kapp suggests that the seventh century game ‘Chaturanga’ may be the first use of gamification), foreign to learning professionals, perfect for all learning situations , easy to create or consist solely of game mechanics. In light of this, educators should take a process oriented approach to applying game elements rather than a goal orientated approach of rewards and outcomes (Kapp, 2012, Llagostera, 2012 Salen & Zimmerman, 2004) in order to let their students engage or in other words, “play”.

**Playing in the “Magic Circle”**

Salen & Zimmerman (2004) suggest that “play is free movement within a more rigid structure” (pp.304). Malaby (2007) claims however that play is a form of activity with three intrinsic features, it is separable from everyday life (abstract), safe (no risk), and pleasurable or “fun”. Taking Salen & Zimmerman’s example of a rigid structure and Malaby’s contention that play is abstract gives the impression of a space outside of reality or a “magic circle”.

Salen & Zimmerman (2004) suggest that the “magic circle” is an imaginary boundary which separates the physical space from the games space suggesting that the player is more or less removed from reality whilst in this space. Salen & Zimmerman (2004) further the idea by suggesting that the framing of the game (which schema is used to understand them) influences if the magic circle is in fact open, closed or a mix of both. Consalvo (2009) however disputes the notion of the magic circle, claiming that gaming takes place in one of the series of frames in our lives; She makes this claim by suggesting that because players can shift between the game world and reality rapidly (thus moving between frames). Also Consalvo (2009) points out that virtual or game worlds are not beyond the reach of morals and values contained in society by illustrating a scenario in Final Fantasy IX Online, where a player was pushed poked and shouted at for being a “gil (gold) seller” (so trying to sell their items for real world currency, otherwise known as the Real Money Trade). This suggest that the player was involved in turning virtual goods into real currency, suggesting that the game world and reality are indeed connected, therefore the player is never really removed from either the game or real world, questioning the validity of the impregnable magic circle. Drawing these two differing views together, the magic circle (or frame) can be seen as a fluid barrier which blurs (and not define) the barrier between the realities.

**Part 2: Alchemy program design**

This first aspect of the program requires students to source their raw materials for their alchemic reactions which can be done in a variety of different ways. Primarily the sourcing of materials would be conducted with a simple map with locations of caches which may contain a hydrogen tank or iron bars or a combination of different materials for students to collect; students then are to return to their alchemy lab to carry out the reactions. How this element of the program is used left up to the teacher, the codes may be distributed around the classroom or expanded throughout the school grounds, a narrative story of a post-apocalyptic society in which students are looking for create ways to create materials to support the re-population of an area could be considered or maybe students are trying to look for ways to recycle organic and inorganic materials to solve future resource shortages can be added to in an attempt to add context to the exercise.

For this example students would be trying to evade roving bandit gangs to bring back supplies to their home base in post-apocalyptic Melbourne (or any other location), Students are motivated to run due to if students fail to outrun the gang then they lose experience and have to start their run over. If in fact students outrun the gang long enough to return to base then they gain experience, to a point where they can purchase ‘perks’ such as early detection system or camouflage to evade their pursuers; however the frequency of the roving gangs become more frequent as the student progresses up the levels.

When a student scans an AR code the software will show information detailing core information surrounding the material as well as a rotatable three dimensional model of the molecule; for example water:

You have found: Water

(123RF.com)

Water consists of two hydrogen and one oxygen atoms and water covers around 71% of the Earth's surface and is vital for all known forms of life. On Earth, 96.5% of the planet's water is found in seas and oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the air as vapour, clouds (formed of solid and liquid water particles suspended in air) and precipitation Only 2.5% of the Earth's water is freshwater, and 98.8% of that water is in ice and groundwater. Less than 0.3% of all freshwater is in rivers, lakes, and the atmosphere.

**Virtual lab**

Students aim to complete chemical journals by splitting and combining compounds as necessary, gradually increasing both player levels and game levels. The game starts off with students bringing low level elements (low atomic mass) to combine into more complex molecules, such as two hydrogen + one oxygen makes water. Players gain experience from effectively combining a range of various elements and completing challenges and by doing so allows them to unlock character ‘perks’, such as collecting more refined materials, access to higher game levels, access to new materials or even a ‘philosophers stone’ to transmute compounds (like gold to lead) etc.

The second aspect of the virtual alchemy lab is that as the students gain experience then new labs with more complex requirements are unlocked. The compounds become progressively harder as the student progresses through the labs, such as combining six carbon atoms , twelve hydrogen atoms and six oxygen atoms to create a glucose molecule; this continues until students are working in a reverse order to break down compounds into their base elements, then reconstructing them as required; however students run the risk or creating unstable or dangerous materials which may burn, explode, irradiate, injure or ultimately kill their character if proper procedures are not met at higher levels. This may be as simple as sequencing their reactions, the choice to heat or cool the compounds or even how each should be handled. As the students create various materials background information is unlocked detailing the history of the material which includes common uses, attributes, place on the periodic table and the scientific representation of the molecule, (eg. Hydrogen is represented by H, but hydrogen peroxide is H2O2).

The last aspect of the game design is that students are to be ranked in their class leader board and receive badges as they fulfil certain requirements, for example “Mastered the basics” after the player has synthesised the first 8 elements as a positive achievement or “Road kill” for repeatedly being caught whilst running for materials.

**Rationale**

The Alchemy! game design is heavily reliant reward structures in order to be successful, which is shown through external rewards of character levels, leader boards and perks (operant conditioning) and development of interest through the process of exploration (socio-cognitive view, active learning). A key attribute to the program is the use of positive and negative achievements to motivate and by taking this approach, the program is trying to be as diverse as possible to engage more learners through the motivation to achieve good badges and avoid the negative ones. (Kapp, 2012, McInerney & McInerney, 2010)

Another aspect of this design is the use of augmented reality, Kuei-Fang, Chen & Huang (2012) propose that augmented reality (AR) is one of the many areas of Mixed Reality (MR), which project virtual elements onto the surrounding real environment as opposed to Virtual Reality (VR) or the more in its more recent manifestation of augmented virtuality where elements of the real world are placed into virtual environments. Kuei-Fang, Chen & Huang (2012) suggest that augmented reality is more cost effective for institutions, more flexible due to developments in smart phone technology and that the programming aspect is easier for educators to engage in. Finally students are more likely to connect or recall by offering content that is manipulable by the individual (i.e. able to be expanded or rotated).( Salen & Zimmerman, 2004). This has been achieved by utilising touch screen technologies on smart devices such as iPads or associated devices.

**Part 3: Outcomes**

The main outcome of this program surrounds developing students’ awareness of various chemicals which shape our daily lives by prompting students to learn the chemical symbol for common molecules. By undertaking an experiential program, students hare becoming literate in being able to identify key aspects of molecules and key processes used in the lab environment. Gee (1992) proposes that researchers think first on “semiotic domains” and then get to literacy in the more traditional sense. He then progresses to suggest that semiotic “is just a fancy way of saying we want to talk about all the sorts of things that can take on meaning” (pp.17) these can be images/photographs, sounds, gestures, equations or objects; even suggesting that people (such as nurses, mother etc.) can act as attachment for meaning rather than just words. Considering this, if students are able to attach meanings to their actions then they are more likely to remember them. Gee (1991) concludes that literacy is mastered through acquisition, not learning, that is, it requires exposures to models in natural, meaningful and functional settings; meaning that students need exposure to content outside of what Dewey (1935) suggests as the ‘traditional school’ setting

Apperley & Walsh (2012) provide context for this in interactive technologies, suggesting that ‘during gameplay, pupils draw on their gaming literacies to accomplish difficult but motivating tasks and develop new knowledge by navigating the complex, changing virtual environment (pp.177)’ This suggests that students must break down the experience, recognise what is required to successfully navigate the learning therefore constructing meaning. Another way of viewing this is how Squire (2006) advocates for the re-framing of video gaming as ‘*designed experience’* by making player agency central importance, and proving an understanding what players do with them and the meanings that players construct through these actions (Malone, 1981; Murray, 1997, cited in Squire, 2006)

**Part 4: Critique**

An important aspect to game design is critiquing how effective the game was in the classroom through a process of reflection (simular to the experiential education model shown earlier) However since this game hasn’t reached that point, the critique will be conducted by comparison to major theories of what constitutes a “good” game design

The game design also was aimed at promoting physical activity through covertly engaging the students in interval based training through the gamification of physical activity; A meta-analysis conducted by Peng & Crouse (2011) found that results from ‘active video games” (AVG’s) displayed simular results to moderate physical exertion, which correlate with a study conducted by Alasdair, Brown & Meenan, (2013). Theoretically the students engaging in a form of physical activity , but risk engaging in the activity on a superficial level since most of the effort and focus is on the science aspect of the activity.

Kapp (2012) suggests that game designers need to consider the role of rules, conflict/competition/cooperation, time, reward structures, feedback, levels, storytelling, ‘curve of interest’, aesthetics and replayability. This has been achieved to some extent, with the game consisting of a combination of rules, competition and game/player level progression; however the design is underdeveloped as it does not consist of a substantial storyline. Storylines or narrative gameplay are critical for fostering higher order thinking skills (Kapp, 2012), which limit the opportunities for authentic learning to take place. Thus regrettably the Alchemy! design seems to act as trivialisation of learning as the learning process may be more effective using alternative means.

**Conclusion**

Designing a universal game in education is near on impossible to accomplish, with countless theories on reward structures, effective learning and knowledge development compounding the process. Also this paper has shown that educational software and technologies cannot replace that value of the educational professional in the classroom no matter how innovative the designer tries to be. The main outcome however of this paper was to highlight the need for game designers to actively critique and reflect on the experience of game design and the effectiveness of their program in achieving what the designer has set to accomplish.

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