Measuring Learner Engagement to Create a Gameful Learning Environment

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1 RESEARCH PROBLEM

If educators were to be skilled game designers, then they would be better equipped to design engaging education scenarios. The importance of learner engagement within a learning environment is without question. Yet there can is ongoing struggle to quantify learner engagement throughout teaching strategies. In the field of game design, engagement is a fundamental metric used to assess player participation throughout, often compared or interchanged with the term Flow.

It is the aim of this research to investigate the potential for educators to leverage game design mechanisms, proposing that educators would then be better equipped in designing engaging educational scenarios for the classroom and able to adjust the accordingly.

Subsequently this research aims to offer a framework for designing educational scenarios, based around a core principle: we must stop being educators dissecting and borrowing game elements, but rather that we are game designers building educational scenarios. This will allow for identification and definition of a framework for Gameful Learning by mapping engagement using established game development formats like that of Mechanics, Dynamics & Aesthetics (MDA) (Hunicke et al. n.d.). and Flow (Csikszentmihalyi et al. 2014) to established engagement metrics such as the Student Course Engagement Questionnaire (SCEQ) (Handelsman et al. 2005) providing a quantifiable outcome for use in class design.

2 OUTLINE OF OBJECTIVES

There is a current belief in education that the traditional learning formats have become boring and motivation needs to be more heavily emphasised in the planning of learning environment (Lee and Hammer 2011). The goal of many researchers has become that of finding a means to drive the intrinsic needs to increase motivation and tap into the learner's inner desire to progress (Dele-Ajayi et al. 2016; Fowler 2016; Cooke 2016). The commercial games industry as a medium has tapped into this inner desire to progress, as such the games industry has become heavily dissected in the search to find methods to increase learner engagement (Bonsignore et al. 2014).

In game design, player engagement has been identified by some as flow (Csikszentmihalyi et al. 2014), where the game needs to find a balance between boredom and frustration specific to each individual's needs, not all players are at the same level. In investigating this information there is a massive visible disparity between industry standards and academic approaches, in that games are designed from the first iteration with specific intent, yet in an academic scenario, it can be seen to be an additive rather than a foundation of construction. Another difficulty is that flow, fun, motivation and engagement have often been used interchangeably, especially in industry literature making it more difficult to define the exact experience under review.

However, it can be clearly seen that the current need to better understand engagement in games is essential. Gamification can go too off topic if not managed, and similar concepts like problem-based learning (PBL) and Game-based learning can be perceived as too restrictive on the learners. Although both methodologies clearly yield the potential for mastery of a topic. Picking and choosing elements although having negative connotations when considering consistency, it can also potentially yield positive results in allowing the games of education designers to better reach their audience. Not all games are designed to be the same so why should all learning scenarios? Even if we consider the just the gaming element of rewards, and often overused and misunderstood concept, we need to consider not all students are motivated by the same rewards (Veltsos 2017). The games industry has identified the potential negative influence of points or scores and have adapted to eliminate these as the focus of a lot of titles (Sweetser et al. 2012).

A fundamental principle of this research is that a focus on ludology (Huizinga et al. n.d.; Raessens 2006) as a tool for building is key. Much of the current research into games as a medium is based on dissecting games to understand the principles of what make them effective (Gee et al. 2008; Dicheva et al. 2015; Downs et al. 2014). Yet the game developers are using ludology and principles of game design as the method to construct their products from the first iteration. We propose that instead of deconstructed games, both gamification and game-based learning would benefit from creating their material from the principles of ludology and game design, which may promote better control over a designed environment with tangible and measurable outcomes. This research is grounded in this approach, providing measurable outcomes in response to an intentionally gameful environment.

3 STATE OF THE ART

When considering education, if it were perceived as a journey with knowledge as the destination, this would be comparable to the experience of a game, exams and practical are game challenges, learning outcomes are win conditions, and as a game the aim is to change the player/learner over the journey.

It has been thoroughly studied as to why students may want to learn. In adult learning or andragogy for example it is proposed that adults learners learn due to two intrinsic factors. They want to or they need to (Knowles 2003), motivation is a key factor for engagement in education. This is true in the field of videogame development as to what makes a player want to play a game (Lazzaro 2004; Tanis & Jansz 2008; Hamari et al. 2015). As such there is growing interest in the means to leverage motivational methods used in videogames within education.

A core challenge facing this transfer of motivational methods is that games, although natural learning environments fail once they no longer feel like a game (Bissell 2010). The idea that a game must feel like a game (Murray 2006) is not new and a lack of understanding in attempting to implement games scenarios without the core knowledge of game design can result in a contrived game environment, as most game designers will state that the game is not the experience, but rather the means to achieve the experience.

Notably creating a learning environment of such diversity and means is not in itself without concerns. Creating such gamified scenarios has been noted to be highly expensive and time consuming (Kapp 2012). The time involved in devising a feasible and tested design is measurable only against the extent of the desired learning outcome, and for higher level learning scenarios like that of evaluation or creation, from Blooms revised taxonomy 2001, could lead to exponential growth in a learning environment. This means that any facilitator of learning would be required to pre-empt that students had the potential to go well beyond the desired learning outcome. However this is not unlike the concerns of established learning methods such as problem-based learning (PBL) or flipped classrooms. In fact, both these scenarios encourage such development whilst having a facilitator to guide learning outcomes. This is supported by the research of Gee and Hayes (Gee & Hayes 2011), who has stated that although there is a current popular desire to allow students to develop without guidance, that this can allow students to get misdirected into answering the wrong questions, where they may find good answers, it is the role of the educator to direct the learning, as it is the role of the game designer to make sure the player finds the end of the game and completes a journey. Good game designers are proficient at this. Sandbox games, like that of the Elder Scrolls & Fallout series, are designed to allow the players to explore in any direction. Through a variety of means, yet through strategic game design players can be driven to finish the game and see specific parts in the journey.

In recent years many researchers have investigated potential frameworks for implementing gameful learning scenarios (Dele-Ajayi et al. 2016; Cooke 2016) with many focusing on the impact these designs have on participant engagement. However much of this research has been completed using qualitative methodologies proposing non-quantifiable outcomes for these goals, instead choosing to focus on impact to learner grades and results as the tangible outcomes.

Although this field has be extensively researched and many great resources have been established, such as Gee’s 36 Principles of games (Gee 2007), in itself a non-comprehensive list of principles that can be adopted from games into other formats like education. There is a current movement that believes that the means and interest of gamifying learning environments is only now coming into its “hype phase” (Dicheva et al. 2015) and will grow in popularity. Game Jams and Hackathons being naturally gamified learning scenarios (Fowler 2016) were an ideal proving ground for this research. As without negative academic repercussions, skill development and engagement could be monitored.

Game Jams have also been repeatedly identified as naturally gamified learning environments, as they embody the process of learning by doing (Fowler 2016; Knowles 2003). It has been stated that the impact of research into game jams has in fact brought an awareness of learning to Game Jams creating a more professional atmosphere among attendees in recent years (Eberhardt 2016).

In game design MDA (Hunicke et al. n.d.) is an iterative approach to design and tuning, allowing game designers to anticipate how changes will impact each aspect of development within the framework and the resulting implementations. By moving between MDA's three levels of abstraction, designers conceptualize the dynamic behaviour of a game system. In industry MDA is widely considered to be the bridge between the game development and the game design

The Mechanics are the base components of the game rules, player actions, the algorithms and data structures in the game engine. For a designer mechanics are the formal rules of the game environment. The rules that define how the game is prepared, the actions players can take, the win condition, and the enforcement of essential mechanisms, describing components of the game at the level of data representation.

In adapting MDA to a learning scenario, we interpret the mechanics as the rules and the interactions described with algorithms and data structures by which to alter the experiment or environment, utilising the formal elements of game design as a foundation structure to create each scenario (Salen & Zimmerman 2004). These formal elements of game design give the learning facilitator a tangible set of variables within which the interactions of the learning environment can be changed.

Game development defines the aesthetics as the emotional responses evoked in the player, when they interact with the game system (Hunicke et al. n.d.). These are describing the player's experience of the game, their enjoyment, frustration, discovery, fellowship among other variables. For a game designer aesthetics is where we would look for a flow state to be achieved and examine engagement.

Aesthetics corresponds to investigating the player experience within observations and measurements of engagement and the player's expectation of it. In games the principle of Flow is used as a defining measure for engagement as it is well documented and quantifiable (Broek 2012; Csikszentmihalyi et al. 2014).

Finally, in MDA the dynamics are the run-time behaviour of the mechanics acting on player input. Dynamics are the part of the mechanics that player can see (Hunicke et al. n.d.). It describes what the outcome is when the player interacts or sends an input to the game. Dynamics describe how the rules function when acting in response to player input. In game development this clearly demonstrate how the player does with the game when following the path, the designer laid out.

Dynamics describe the real runtime experience of the player/learner. Key in utilising this for education is the ability to define quantifiable metrics and identify relations to the educational identity of students and their engagement factors.

Player experience begins in the aesthetic level of a game and can later interact with the dynamics but never with the mechanics. A designer starts with the mechanics and then addresses the dynamic aspect of the game.

In development it is usual, when working with games, to consider both the designer and player experience and aim for the best player experience. This can be directly paralleled to the experience of a educator designing a learning experience for any student.

In psychology engagement is described as a construct with both behavioural and affective components. Behavioural components describe engagement by incorporating a student's individual approach and style of learning, their motives to study, and their strategies to success (Herrmann 2013). Affective engagement with an under-graduate course describes the amount of emotional involvement a student has with their learning of the material on the course, and their emotional commitment to studying the course material. (Brown et al. 2017)

For preliminary iterations of this research a questionnaire was used in natural gamified learning scenarios such as Game Jams. This is a formative scenario assuming minimum impact to formal learning scenarios. In the initial experiments the difficulty of flow, fun, motivation and engagement being used interchangeably was addressed, thus a primary focus of the first experiment was on Motivation as a signifier of Engagement. This was deemed as a less tangible metric following the studies and more robust Engagement methods were adopted for later experiments (Handelsman et al. 2005; Brown et al. 2017).

Secondary iterations took place in third level undergraduate Art and ICT based modules in a privately funded higher education institution in the schools of Animation and Game Development. The study was approved by the Ethics Committee of both NCI and Pulse College. Demographics of the students were not collected for this study and student identity was anonymised. This research specifically targeted the second semester modules across both schools, taking a longitudinal approach to the study.

4 METHODOLOGY

4.1 Pilot Study

Initial research began with observation of a 28-hour Game Jam in third level institutions with undergraduate participants using the Experience Sampling Method (ESM) with a small sample group, n = 13. As a pilot study sample this is in line with sizes like that suggested by Julious (Julious 2005) and van Belle (Van Belle 2008) among others.

This phase of research is aimed at testing flow measurement techniques like Experience Sampling Method (ESM) and testing/setting the precedent for the 8 controls of the Mechanics as well as LIWC (Tausczik and Pennebaker n.d.; Boyd and Pennebaker 2017), this initial data is utilised to understand the potential impact that the research could have on the participants of a game jam, correspondingly resulting in forms of observer bias and/or Hawthorne effects.

The selection of LIWC, was based on its ability to measure computational affect, psychometrics, and sentiment analysis in written text. Many studies (Kramer and D.I. 2010; Kramer and D.I. 2012; Lindner et al. 2015) have used LIWC to predict emotional state(s) thus making it a useful mechanism for studying engagement and changes in engagement over time via open free text questions, or other forms of learner-generated text.

The game jam mechanics were plotted as the mechanics using the formal elements of game design. And although good data was maintained this initial study, the results and interaction were solely utilized for improving the experimental process.

From the initial experiment, it was found that during an intense time critical scenario some game jam participants would forget to fill out paper-based survey forms and would only complete them with the personal interaction of an individual. For this reason, it was decided that an independent body, unrelated to either the jam or the research, would be brought in to follow up on assuring questionnaires and feedback was completed.

Each participant was randomly sampled 4 times over period of the Jam. A major constraint of game jams is the time, so the introduction of the ESM could be perceived as a detractor, although each participant was a volunteer and providing expressed consent to participate in the study. Participants had the option to not participate and were informed of how provided data would be used and anonymized.

A positive and negative question testing concentration was put in as a control to observe consistency in participant's answers. This question construct is in place to mitigate inconsistencies in self-report via click-through like respondent behaviours (e.g. always answering 1).

Each participant reported on multiple elements of challenge, emotional states including boredom and anxiety at each testing stage. With the challenge (dynamics) alternating from below to above the perceived participant skill level (aesthetics). This is reflected in further feedback data from the participants who noticeably document that their stress levels increase with the challenge yet retain a relatively consistent level of positivity.

An interesting finding was that participants primarily start the events viewing their skills as higher than the level of challenge, this reverses in the second sampling settling into a natural competitive trend for the rest of the event.

The results were then compared to feedback run through LIWC also taken at each sampling phase, as well as observations of the participants.

In this pilot study the objective was to observe the process of open questions to tailor the experimental design and to provide insight on how these questions may be answered and how long the answers could be. Correspondingly, participants were asked to provide feedback, through a debriefing survey. The nature of the ESM and observation is seen as intrusive and a challenge to the time constraints of the participants and means that going forward it needs to be streamlined for practical application, before it can be utilised in a classroom scenario.

4.2 First Experiment

The first experiment was completed during the Global Game Jam 2017 (GGJ), all data was anonymised. A singular game jam site was chosen in a third level institute, populated by a mix of 62 students from STEM undergraduate courses. 69% of participants completed all 4 measurement stages. From those who didn't complete all 4 it was either due to arriving over 12 hours late or leaving at least 12 hours early. No one declined to participate, and the 19 incompletes were invited to participate in the feedback the same as the other participants for inclusion purposes.

Each attendee was intermittently asked to fill out the questionnaires at 4 intervals. The Game Jam is a natural environment demonstrating the essential characteristics to gamify an educational scenario as it follows some essential game elements such as: (Stott and Neustaedter n.d.)

- freedom to fail – there is no penalty for not completing a game. Similar to a formative assessment.
- rapid feedback – through peer review and engagement
- progression – a clear deadline and project goals
- storytelling & narrative – the objective is the same for all attendee, create a playable game to fit the theme set by GGJ

4.2.1 First Experiment Method

Measures of central tendency were computed to summarize the data for the motivation variable. Measures of dispersion were computed to understand the variability of scores for the motivation variable (N = 43, M = 4.33, SD = 1.363). With 43 participants, each was randomly sampled four times over a 48-hour period, totalling 172. Each variable is measured on a 7-point Likert scale.

It appears that most students in the game jam were of above "average" motivation. However, based on the standard deviation, it looks like the motivation varied from average to high.

A one-way ANOVA between subjects was conducted to compare the effect on motivation over four samples taken during a game jam.

A Pearson product-moment correlation coefficient was computed to assess the relationship between the motivation and a range of self-reported observations.

4.2.2 First Experiment Results

The mean for participant motivation in the first sample is 4.95, decreasing in sample 2 to 4.47. The mean decreases again in sample 3 to 4.09 and in sample 4 to 3.79. Although this is a nominal drop, it is expectant that over the 48-hour period participants would see a drop-in motivation as exhaustion sets in. The results were statistically significant, and correspondingly a Tukey post hoc test is used to compare each stage to every other stage.

Post hoc comparisons using the Tukey HSD test indicated that the mean score for the sample one condition (M = 4.95, SD = 1.045) was significantly different than the sample three (M = 4.09, SD = 1.461), sample four (M = 3.79, SD = 1.474). However, sample two (M = 4.47, SD = 1.182), did not significantly differ from sample one. Although Sample two (M = 4.47, SD = 1.182) was also found to be significantly different than sample four (M = 3.79, SD = 1.474).

With a Sig value of less than or equal to .000 it can be concluded that there is a statistically significant difference between the four samples. There was a significant effect on motivation at the $p<.05$ level for the four samples [$F(3, 168) = 6.362$, $p = 0.000$]. It can also be concluded that the differences between condition means are not likely due to chance and are probably due to the motivational changes over the four samples.

There were large positive statistically significant correlations found between Motivation and Concentration (r = 0.502, n = 172, p = 0.000), Happy (r = 0.536, n = 172, p = 0.000), Active (r = 0.516, n = 172, p = 0.000), and Excited (r = 0.642, n = 172, p = 0.000). This means that changes in Motivation variable measured, are strongly correlated with changes in the Concentration, Happy, Active, and Excited. As such it can be concluded that there is a strong relationship between motivation and these variables.

When compared to the MDA aesthetic eight potential scenarios of fun (Hunicke et al. n.d.), we can see a link between three of these scenarios and the four strong correlations to motivation identified within the data.

- Sensation - Happy/ Excited
- Challenge - Concentration
- Submission - Active

The data was also analysed in LIWC as all participants were asked at each interval to fill out three open ended questions, about their experience at that moment in time and outside factors they are contemplating.

The need for improving the measurement method was apparent from this study and research suggested a less intrusive approach would be necessary. The interval checks were viewed as frustrating and the usage of motivation metrics as a measure of engagement were perceived to be a tenuous link.

4.3 Second Experiment

The Student Course Engagement Questionnaire (Handelsman et al. 2005) was administered, as an observational non-manipulative design, to all students in semester 1 of first and second year Animation and Games Development courses, across all modules. Data were collected for the last 6 weeks

Table 1: Factor analysis of SCEQ. Animation Group Week 1 compared to the Handelsman et al. (2005) groupings.

Item	**Factor**				*Handelsman et al. (2005)*
	1	**2**	**3**	**4**	
Q11	0.807				**2**
Q8	0.709				**2**
Q18	0.692				**3**
Q23	0.644				**1**
Q7	0.641				**2**
Q12	0.628				**4**
Q22	0.615		0.497		**2**
Q13	0.614	0.472			**1**
Q21	0.613		0.485		**2**
Q19	0.506				**3**
Q15		0.788			**4**
Q14		0.708	0.452		**1**
Q4		0.658			**1**
Q16		0.641			**4**
Q5		0.567			**1**
Q10			0.869		**1**
Q9			0.824		**1**
Q20			0.578		**1**
Q17			0.547		**1**
Q1				0.804	**3**
Q3				0.803	**3**
Q6				0.597	**3**

Extraction Method: Principal Component. Analysis. Rotation Method: Varimax with Kaiser Normalization.

of the semester for all enrolled students.

The SCEQ was chosen as it is a robust and tested metric with a clear relationship to course engagement. The SCEQ questionnaire comprises of 23 questions employing a 5-point Likert scale. All questionnaires were administered by a third party not connected to the research, through an online form that students were asked to fill out before class time. Participation in filling out the form was entirely voluntary, and all students were given appropriate instruction on the purpose and outcomes of the questionnaire.

Handelsman et al defined the four factors of engagement as (Handelsman et al. 2005):

1. **Skills:** include general learning strategies that one can use to attain intrinsic and extrinsic rewards and may be related to the level of academic challenge
2. **Emotional:** represented through emotional involvement with the class material. Traditionally invisible to the educator.
3. **Participation/Interaction:** represented through participation and interactions with teachers and fellow students.
4. **Performance:** related to extrinsic motivation and to performance goals rather than learning or mastery goals

An exploratory factor analysis was performed on all questionnaire responses using Principal Components Analysis with a Varimax Rotation. The rotated component matrix was utilised to estimate the correlations between each of the variables and the estimated components.

Validity of identified factors were further evaluated using a Cronbach's alpha coefficient as an estimate of the squared correlation of the estimated values of samples obtained from the Likert Scale and their true values.

Finally, a Spearman's Correlation was used to measures the strength and direction of association between all variables.

4.3.1 Second Experiment Method

The questionnaire was administered to the Animation (n=45) and Game Development (n=96) student groups weekly. These cohorts have overlapping modules and events sharing a close student experience. Questionnaires were administered for 6 weeks. Each week participation numbers were recorded with the Games Development students dropping to 38% completion rate for the questionnaire at a low and Animation to 47%.

The initial solution to the exploratory factor analysis using a 4 factor solution was administered to each cohort every week.

Table 2: Factor analysis of SCEQ. Animation Group Week 2 compared to the Handelsman et al. (2005) groupings.

Item	**Factor**				*Handelsman et al. (2005)*
	1	**2**	**3**	**4**	
Q21	0.856				**2**
Q22	0.752				**2**
Q8	0.705				**2**
Q11	0.624				**2**
Q19	0.607			0.518	**3**
Q18	0.540			0.523	**3**
Q7	0.528	0.474			**2**
Q15	0.518	0.453			**4**
Q13	0.515				**1**
Q16	0.500	0.497	0.469		**4**
Q12	0.481	0.467			**4**
Q4		0.786			**1**
Q5		0.751			**1**
Q23		0.742			**1**
Q17		0.613			**1**
Q9			0.787		**1**
Q10			0.754		**1**
Q14		0.486	0.688		**1**
Q20			0.572		**1**
Q1				0.818	**3**
Q3				0.665	**3**
Q2				0.546	**3**

Extraction Method: Principal Component. Analysis. Rotation Method: Varimax with Kaiser Normalization.

4.3.2 Second Experiment Results

Examining a small sample snapshot of the Animation Students sample in week 1 the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.837, and the significance of the Bartlett's test of sphericity was <0.0001 – these two statistics confirm that the exploratory factor analysis technique was appropriate to use on the data.

In week 2 for the Animation Students the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.778, and the significance of the Bartlett's test of sphericity was <0.0001 again confirming that the exploratory factor analysis technique was appropriate. Spearman's Rank Order Correlation for week 1 and 2 is .481 indicating a Moderate positive relationship.

The student focus shifts between weeks, as can be clearly seen from the Animation Student examples in week 1 (Table 1) and 2 (Table 2). Using the factor descriptions put forward by Handelsman et al. we can see there is a higher focus on the Emotional Engagement in week 2 in the first factor, and Performance in the second factor. These metrics can be seen in the student behaviour throughout the weeks and in week 5 there is a major shift to Participation/Interaction being the highest focus and emotional dropping to the bottom. This shift visibly corresponds to submission of group-based projects.

5 EXPECTED OUTCOME

The need for improving engagement measurement is apparent and research suggests allowing for a less intrusive approach is key to the success of this research.

This research aims to provide a framework, not as a standalone construct, but rather more as an instructional design tool allowing for quantifiable feedback in an active learning environment.

The primary research goal is to develop a practical framework for designing engaging classroom content that can be measured. To achieve this, secondary research goals were undertaken:

RQ1 Identifying the appropriate game design mechanisms to apply to classroom design strategies.

RQ2 Examination of learning environments to identify measures of engagement, testing unobtrusive and unbiased observation methods of monitoring.

RQ3 Quantifying and approximating engagement evaluated via ESM, Flow, Surveys, Computational

Linguistics, defining and quantifying metrics of engagement e.g SCEQ.
RQ4 Measurement of a live learning environment, examining Flow and engagement on an ongoing basis.
RQ5 Deriving scenarios where the framework could enhance, extend and improve student engagement.

6 STAGE OF THE RESEARCH

By quantifying metrics engagement, a facilitator can establish a precedent to justify altering the gameful scenario through controlled mechanics. The need for improving the measurement method was apparent from this study and research between the first and second experiment.

By adopting the SCEQ measurement as a longitudinal study the researcher was able to create a tangible view of multiple groups in a learning environment without encroaching on the learners or teachers experience. To that end the results thus far support the conclusion that through these correlations a quantifiable and adjustable approach to gameful learning is attainable.

Furthering the research the next stage will be to map game based heuristics, like that of GameFlow (Sweetser et al. 2012) to the engagement metrics to help facilitate class design in a gameful manner.

The author intends to further this research by measuring the impact of altering individual game mechanics in a formative undergraduate educational environment.

Subsequent research will then be completed into the area of altering the individual mechanics to quantify their impact on the learner's engagement. This will be carried out utilising the formal elements of game design and adhering to the essential characteristics to gamify an educational scenario and to create a framework for extrapolation of Mechanics that can be implemented into class design creating a gameful method for designing education.

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