

Learning Mathematics Through Serious Games: An engagement framework

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Abstract- Digital games have become part of childhood and adolescence. The debate has moved from should teenagers play digital games to how to gain benefits from this gameplay. Researchers predict that technology-enhanced learning will increase with educational computer games (serious games) playing an important role. Although serious games are often built on established educational theories, they can also appear boring and struggle to engage the learner. Analyses of serious games demonstrate that many do not offer an entertainment experience comparable to or even recognizable as relatives of the entertainment games familiar to many players. However, a high level of engagement by the learner is viewed as necessary to provide a strong learning environment. The long-term aim of this study is to explore how digital games can support a more engaging and effective mathematics learning experience. This first stage has taken a qualitative grounded theory approach to explore the engagement factors of digital games among young people (aged 7 – 16 years). Analyses of data gathered through a combination of surveys and interviews have led to a framework of engagement factors. This provides a basis for designing serious games that are effective by being both engaging and educational.

Keywords - *Game-based learning; serious games; technology-enhanced learning; young people; active learning;*

I. INTRODUCTION AND BACKGROUND

One of the primary goals of digital game developers is to create enjoyable games [1] and for that to happen, a game must have characteristics that make players want to return to play it [2]. Likewise, for developers, academics and education providers to maximize the potential serious games offer to classroom teaching, there needs to be an increased focus on how to design educational games that are engaging and support effective learning [3]. A key finding Shute et al. [4] is that children who find it difficult to do exercises in school and complete homework are still eager to play digital games and participate in other ‘fun’ activities outside the school day. This

suggests that making education fun could increase a child’s engagement.

Research indicates that children can regard mathematics as abstract, boring, and unconnected to the real world [5] [6]. Anecdotal evidence coupled with poor performance among children has indicated that there is an ongoing issue with engaging children to learn mathematics effectively in the classroom. As one mathematics teacher from a Nigerian School comments: “They do not like it (mathematics), many of them see it as hard and impossible, then they get disinterested in the classroom”. Together this evidence provided the impetus for this current study, focusing on how to use digital games with children to support a more effective mathematics learning experience.

Researchers have argued that games have the capacity to attract and motivate reluctant learners towards particular subjects in ways traditional methods cannot [7] [8] [9]. This is because children appear to enjoy and have more concentration while doing computer-based learning activities compared to traditionally delivered ones [10].

Despite the potential that serious games offer, there are concerns and questions about how these technologies can foster deeper learning [11]. Kerawalla and Crook [12] for example found that interest triggered and mediated by educational software may be temporal. This led the research team to conduct this initial study to explore the factors that can trigger and sustain engagement, and provide a greater insight into how serious games can be designed and developed to not just create interest and motivation, but to also foster deeper engagement and learning.

II. RESEARCH APPROACH

Grounded theory, developed by Glaser and Strauss in the 1960s [13] is a research method where the theory develops from the data (is grounded in the data itself) and is appropriate for exploring human behaviors and interactions [14]. Thus it has been adopted in this study to explore what attracts young people to particular games, what keeps them engaged and what provides the impetus for them to keep returning to a particular game. A mixed method comprising a questionnaire combined with an interview was used for the primary data collection process. The questionnaire was used to explore what kinds of games young people are playing and why they play them. This was followed up with a short structured interview to provide further insights into the reasons they choose to play certain games and what the engagement triggers are. Engagement is a complex construct and as such should be explored by considering the responses of players to the gaming experience [18].

The questions for the questionnaire were constructed using a theoretical framework comprising the key engagement factors for gaming identified from the literature (Table 1). The questionnaire gathered demographic information, average playing time a week, a ranking of the five most played games, type of devices played on as well as genre of games played. As the target audience was young people, the interview was kept deliberately short to maintain their interest and participation. The interview employed structured but open-ended questions in order to avoid leading the respondents to biased answers and opinions. Three main questions were asked: ‘what are the features that attract you to a game?’; ‘what are the characteristics of a game that make you continue to play?’; and ‘what makes you come back to a game?’

S/N	Factor	Source
1	Challenge	Csikszentmihalyi [15]
2	Interest	Malone [16]
3	Social Interaction	Prensky [17]
4	Feedback	Csikszentmihalyi, Malone [15] [16]
5	Clarity of goal	Malone [16]
6	Immersion	Csikszentmihalyi [15]

Table 1. Theoretical factors and sources

III. RESULTS AND ANALYSIS

In total, 37 males (73%) and 14 females (27%) completed the questionnaire. Ten (7 males and 3 females) were further interviewed. The respondents’ average age was 11.5 years (range: 8- 16 years old).

Their responses indicate that the majority of respondents were regular gamers with 47% reporting that they play between 5 and 20 hours per week. The highest percentage of respondents (86%) played games on tablets, followed by the Xbox (60%) while the PlayStation was the least used device (24%). In terms of the ranking of the five most played games by each person, 64 different games were named. Minecraft topped the ranking score with 1964, followed by Candy Crush (815) and Terraria (712) with Lego Lord of the Rings at the lowest rank (60). Adventure (80%) is the most played game genre while flight fighting (10%) is the least played.

The questionnaire had one open ended question. It asked why each respondent play the game they played the most. The responses from this were combined with the qualitative data gathered from the interviews producing an additional 30 answers. This set of data was cleansed by removing null responses and those that were too generic e.g. ‘I like everything about the game’. The resulting set of data was separated into 118 statements. These were tagged and organised to extract elements of engagement. Applying focused coding [19] on the engagement factors, the factors were checked for similarities and thereafter grouped into seven categories: creativity, challenge, social interaction, immersion, thematic appeal, visual appeal, feedback, clarity of goal, rewards.

These categories were then structured into three main divisions – engagement antecedents, engagement experience, and engagement outcomes. The next section discusses these engagement factors and the conceptual framework for designing engaging games.

IV. CONCEPTUAL FRAMEWORK

Emerging from empirical analysis of the data collected, evidence was provided to support some of the theoretical engagement factors previously identified from the literature (see Table 1). In addition to those engagement factors, two additional factors: creativity and rewards were added while thematic and visual appeal replaced interest.

These factors are now discussed in detail with respect to the data collected.

A. Challenge

Challenge is one of the features respondents reported they like in games they play the most. It is not surprising that challenge comes out strongly in the empirical data collected. Making a game too easy can lead to boredom. A game is challenging if it provides a number of different levels of

difficulty and allows players to use a range of mechanisms and approaches to solve problems or achieve certain objectives. Examples of statements from the respondents include: 'If things get harder and makes me involved in the play'; and 'I come back to play a game I enjoyed the first time I played it and there are new challenges and levels to overcome'. These suggest that building some amount of challenge into a game is key to engaging players in the play. Other responses such as including 'a right balance of easy and hard especially with the tips and instruction' suggest the importance of getting the level of challenge right. This aligns with Bryant and Fondren's [20] work where they found that "Moderate levels of complexity create intermediate levels of cortical arousal which is both optimally pleasing and efficient. Making a game difficult could lead to frustration just as making it too easy may lead to boredom. 'Strategy' and 'thinking' are further terms used by the respondents. One respondent said 'I like how you have to figure the words out with your brain and it really helps you with spelling, writing and reading'; another one reported that she would continue playing a game if 'It makes me think'. This suggests that players get engaged when they are mentally challenged by the game play.

B. Social Interaction

This component of the engagement framework captures the game characteristic that allows a player to share the experience of playing with another person. Some respondents that play multiplayer games against/with friends reported that they were engaged in those games because the games provided a platform for communicating and cooperating with others, interacting with the community and building friendship. One respondent stated they liked the game because 'I can start campaigns and compete against my friends', while another remarked that the game engages him, because 'I can be friends with other people'. A number of respondents reported enjoying the games as they can 'play with the community' and also 'communicate with the teams'. Socializing in games is not restricted to communicating and making friends. Some of the responses suggest that there is a link between competition and social interaction. For example one respondent stated that their reason for continuing to play a game is so 'I can beat the high scores of myself and my friends' while another says 'I love the competition as I can tell my friends I will beat you later'.

C. Immersion

This element of engagement describes the desire of the player to experience the story and be part of the gameplay. This could be considered to occur as a result of engagement. The point where players 'loses themselves' and becomes part of the game can be considered the ultimate point of engagement. At this point, players consider themselves to be 'in the game' [21] [22]. Some respondents reported this as the reason why they would keep playing a game. The interaction with the characters of the game as well as conceptualizing themselves as part of the virtual world is appealing to some players. One

of the respondents said 'I like being involved in the play and experiencing the environment'. The state of being involved in the gameplay sometimes results in unintentionally placing all the focus on the game and somewhat losing sense of the real actual environment the player is in. One respondent says: 'I love the world of the game as I get carried away while playing it' while another said 'because I can see myself in the story, it makes me attached to the game'. This feeling of immersion leads to engagement with the game and a feeling of attachment.

D. Thematic and Visual Appeal

Thematic and visual appeal covers elements of engagement that has to do with interest in the story/theme of the game and in its graphical interface. This could include the characters' appearance in addition to the game itself. Thematic appeal is illustrated through the respondents comments that the reason why they play certain games is that it matches their interests in the real world. For example, one respondent said 'the reason why I play the game is because I love to play football' and another respondent with an interest in trains and railways, said that he played the game because 'I can operate a railway'. This implies that certain players engage with games because of their interest in the subject of the game. Some other responses suggest that the graphical nature of the interface and characters are triggers of engagement for them. For example, a respondent said that he likes games with 'clear graphics that show the characters as real as possible' while another mentioned that 'the art and style' was the reason he likes playing a particular game.

E. Clarity of Goal

This element has to do with how clear the objectives of the game are and additionally whether there are clear instructions and rules of play. In order to initially draw a player to a game environment, the player needs to understand what the objectives of the game are, or at least the initial objectives for the game play. This element is associated with both motivation and achievement as knowing the objectives helps maintain motivation and completing objectives helps with the player's sense of achievement and further contributes to their motivation to continue playing. This desire for clarity of goal is evident from the statements: 'I want to know what the game is about and what I should be doing' and 'I will continue playing a game if I understand what the game is about'. Clear goals provide a sense of purpose that can be easily understood by the player and are essential for motivation and engagement.

F. Feedback and Rewards

Respondents reported feedback as one of the features that they like in a game. A good feedback mechanism in a game can help engage the player. Players like to receive feedback and/or information in order to know if they are making progress, and if their actions are correct or not. This helps players plan and make decisions about their future actions and gameplay. As

one respondent stated: ‘I like to receive updates about my performance and scores’. Other responses suggest that players also view reward as a form of feedback. For example, one respondent said ‘I need to know what to do to get high scores and get the necessary points’. Rewards such as extra lives, points, money, ability to unlock special skills and tools, promotion to a new higher level, all help keep a player engaged in game play and are illustrated through comments such as ‘earning new points’, ‘achieving new things’ and ‘being able to play better’. Having a variety of rewards, feedback mechanisms and progression routes can all support a more engaging experience for the player.

G. Creativity

Providing the opportunity for players to be creative and use their imagination was highlighted as an important factor to maintain a player’s interest in a game. This is a key finding from this study. The popularity of games like Minecraft and FIFA may explain this. Players feel engaged and involved in the game play if they are able to create and control content and other elements of game play. For example in FIFA16, players can create teams, and manage players, as they want. For example two of the respondents reported that the reason they come back to play a game is because ‘it allows me to build anything I want to build using my imagination’ and ‘I can build my own teams and control them’. This feeling of control and creativity is essential to engaging players in the game play. It is also related to achievement and mastery. As one respondent remarked: ‘the reason I like to come back to play is because it gets my attention as I am trying to be creative in order to survive’.

The engagement factors from the data analysis have been used to develop the conceptual framework (see Figure 1). This shows these factors grouped under three main categories: initial engagement, on-going engagement and engagement outcome. Initial engagement factors are those that appear to be antecedents to engagement, they precede and tend to trigger engagement. Motivation is the basis for initial engagement.

This motivation can either be powered by thematic/visual appeal as well as interest in the subject of the game (extrinsic) or clarity of goals, objectives and aims of the game. On-going engagement factors help sustain engagement by providing rewards and feedback, a reasonable level of challenge, a way for players to be socially active during gameplay and ways for them to be creative. Given that the goal of engagement is immersion, it is expected that if on-going engagement can be sustained long enough, a player will get to the level of immersion.

V. CONCLUSION AND FUTURE WORK

This initial research study has focused on exploring why young people find some games more engaging than others. It stems from a strong indication that a more engaging experience can support more effective learning in a gaming environment. However the results from the study indicate that engagement is complex. The diversity of the responses and resulting engagement factors suggest that young people engage with particular games for a variety of reasons. This aligns with research that indicates students have different learning styles. Thus the design of a serious game should cater for this variety and incorporate a broad range of engagement factors and the flexibility to allow players to find their own individual route through the game. Future work is being conducted to determine if any of these engagement factors have greater impact than others and which might be most prominent across age and gender. The resulting framework from this study is being used in conjunction with the results of a technology acceptance model to inform the design requirements for a serious game to be used to support mathematics education in the classroom.

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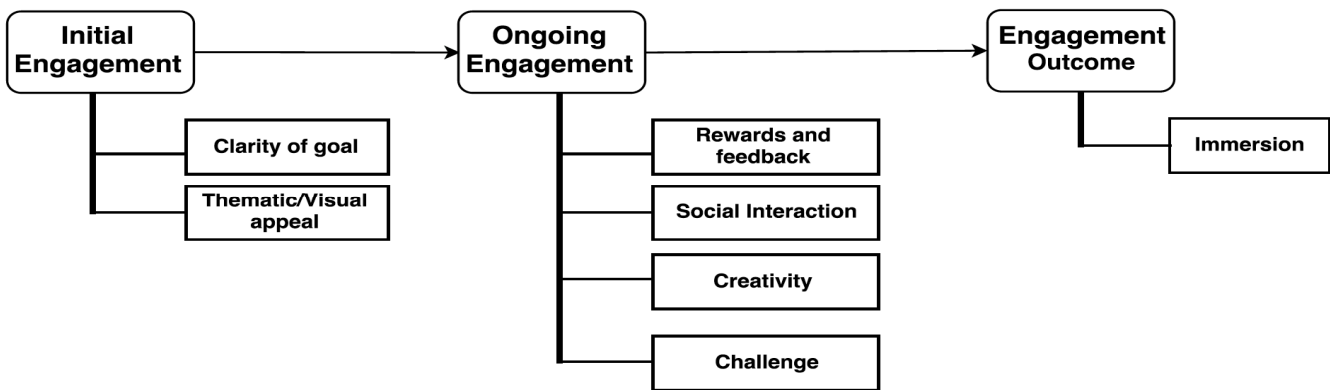


FIG. 1. CONCEPTUAL ENGAGEMENT FRAMEWORK

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