Progress Visualisation, Competition, and Collaboration in Digital Game-based Learning as Audience (DGBL-AA)

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Abstract: This study builds on previous work investigating the efficacy of a novel framework for the design of interactive learning activities based on Digital Game-Based Learning (DGBL). The work presented here provides further explanation of the setup from the previous experiment with the novel framework, DGBL-AA, by considering the provision of a game that a learner can 'observe' as an audience, with parameters related to a linked learning activity. Using a quasi-experimental approach, we analyse children's reactions and perceptions of a game they observe as spectators. While the previous work was grounded in the same principles, this paper finalises the name DGBL-AA and elaborates on the details of the framework. It articulates the underlying principles that facilitate the framework's generalisation across traditional classroom education, GBL, DGBL, and life scenarios, typically phenomena seen in sports. The paper identifies the primary challenges in DGBL and sets specific goals for the framework to address these issues. The experiments and the Frogs game, developed specifically for this study, illustrate the framework's adaptability and offer insights into its potential for widespread implementation. This study evaluates the framework's impact on learning outcomes and student engagement. Our findings suggest that the framework significantly enhances the educational experience, as evidenced by quantitative and qualitative data from the experiments. The experimental group demonstrated higher engagement and better performance compared to the control group. However, there was no significant difference between the competition and collaboration modes of the Frogs game. Future research directions include developing additional games with various progress visualisations to further assess the framework's efficacy. We also aim to explore the long-term effects of the framework on student achievement and motivation. Eventually, a virtual world that allows people to observe and motivate their learning could be created. This could involve implementing the framework in different subjects, age groups, and educational settings to validate its versatility and robustness.

Keywords: Progress Visualisation, Competition, Collaboration, Digital Game-based Learning (DGBL), Digital Game-based Learning as Audience (DGBL-AA), Gamification

1. Introduction

To the majority, learning is a tedious process, and this is especially so for children who can't foresee the benefits of learning. It is well known that it takes considerable time to gain a skill to survive and to become competitive. Malcome Gladwell (2008) claimed that it took about 10,000 hours of intensive practice to achieve mastery of a complex skill. The accuracy of this claim may be debated, but its emphasis on the long journey of learning to become an expert resonates with many people. Tremendous efforts have been made to make learning enjoyable and effective, leading to many practical educational theories and designs to facilitate learners' achieving their goals. With modern technologies, digital game-based learning (DGBL) has flourished.

Much research has pointed out that instant positive feedback is pivotal in motivating and engaging learners (Monteiro et al., 2021). In DGBL, progress bars, badges, leaderboards, and learning journey maps are used to embody a learner's progress and provide positive feedback. In this way, a long learning journey can be divided into short trips so learners can have clear, reachable goals and are encouraged by each milestone they achieve (Ma et al., 2021) However, progress visualisation embodiments, such as progress bars, badges, etc., have been shown to be short-lived as they function more as "extrinsic incentives" that are effective in promoting performance, rather than intrinsic motivation and enjoyment of the task. Further research is needed to understand the nuances of their design and implementation, such as "timing, visual presentation, phrasing, or fulfilment logic", to enhance motivation and performance (Groening & Binnewies, 2019 Intrinsic motivation is generally more effective, and blending progress visualisation with competition and collaboration may increase motivation for young learners. This research explores this blend's effectiveness in DGBL.

When orchestrating the research, theories and ideas from the literature review and life observation were generalised to form a guiding framework, Digital Game-Based Learning as Audience (DGBL-AA), for relevant experimental design. In a nutshell, this framework innovatively utilises intensive learning, DGBL, and motivation to achieve efficient learning by separating learning time and gamifying progress visualisation.

In the first exploration of this concept, a study with fifty-four children aged 8-9 was conducted in 2023. The participants were organised into three groups: controlled, competition and collaboration. The study specifically

focused on the impact of the progress visualisation element of DGBL on learner engagement and performance. Results indicated that the setup had the potential to significantly enhance and deepen learner engagement. Children experiencing the competition condition achieved better than the collaboration group, and both groups experiencing a gamified learning experience showed good motivation.

2. Literature Review

2.1 Minimise Distraction and Maximise Learning Time

Traditionally, educational theories emphasised the importance of minimising distraction and maximising learning time (Leonard, 2003). Typically, rules regarding behaviour, talking, movement, and interactions were produced to reduce disruptions and ensure that the classroom environment remains conducive to learning (Petty, 2001). However, the effectiveness of this setup received a lot of criticism. Critics argue that this approach could fail to cater to diverse learning styles and needs, leading to disengagement for students with short attention spans (Khalaf & Zin, 2018). Although challenged, these theories are still valued and impact today's educational environment in various ways. For example, Schools segment days into periods dedicated to specific subjects, establish classroom rules and maintain order to keep students focused (Mcleod et al., 2003). To learn well, minimising distraction and maximising learning time is still common sense. It is the maintenance of engagement that troubles educators.

2.2 Game-based Learning (GBL) and Digital Game-based Learning (DGBL)

To maintain engagement in learning, some educators have investigated the role of play in enhancing student interest and participation, such as Friedrich Froebel's (1782-1852) educational toys (Roszak, 2018) and Maria Montessori's self-directed play (Montessori, 2013). The underlying concepts of using game-like elements (point scoring, progress bars, badges, etc) to engage and motivate learners have been part of educational strategies for centuries. The term "gamification" was coined in the digital age, referring to using game elements in non-game contexts, and gained popularity in the early 21st century (Sanchez et al., 2020). Effective implementation of game elements, not just their presence, fosters engagement (Boyce, 2014). This critical feature was inherited by the subsequent development of digital game-based learning (DGBL).

With the rise of PCs and digital games, DGBL gained recognition in the 1980s and 1990s and was popularised by Marc Prensky's book "Digital Game-Based Learning" in 2003 (Prensky, 2003). Modern technology and the Internet have further energised DGBL, leading to many educational serious games.

2.3 Costs in DGBL

Serious games make complex subjects accessible, offer intensive interactions with instant feedback, and reach a broad audience via the Internet. However, the major obstacle to the implementation of DGBL in the classroom is the "inefficient allocation of available financial resources" (Kaimara et al., 2021). As Liberona et al. (2022) concluded: Existing games are cost-effective but not personalised. Developing new games is costly, ranging from $60,000 to $300,000. Platforms cost $15 to $125 per student, with the average price rising to $50 per student around 2022.

2.4 Learning Curve and Distractions in DGBL

Even if the accessibility of serious games is available, the excitement and entertainment value of the game can overshadow the educational content, making it difficult for students to stay focused on learning objectives. As Young et al. (2012) pointed out: "overly complex game mechanics can compete with curricular elements for attention, resulting in a greater number of misconceptions or interference with students". The time and effort required to understand how to play the game and navigate its features can be significant, potentially detracting from the time spent on actual learning content (O'Neil et al., 2005). This goes against the common sense discussed in section 2.1. Correct design can avoid this problem (Pasqualotto et al., 2023), but it increases DGBL development costs due to the required effort and resources.

3. Theoretical Framework

3.1 The DGBL-AA Goals

Based on the literature review, it can be concluded that to retain the advantages of DGBL and avoid its shortcomings, the setup must achieve these three goals:

- Goal 1: Minimise learning curve and distractions and maximise learning time in DGBL (See sections 2.1 and 2.4).
- Goal 2: Sophisticated designs to engage learners and motivate them for continuous learning. (See section 2.2).
- Goal 3: Low cost and catering to the needs of various classes (See section 2.3).

The first one is about the reconciliation between learning and gaming time. The second one is to fulfil the goal of DGBL. The third one is more like an impossible mission due to the number of subjects, schools and the nature of software development.

3.2 The Inspiration From Sports

Achieving all three goals is challenging. However, we can find inspiration in our daily lives. Sports provide an example where games do not distract from daily tasks and still engage us. Consider a football match: two teams compete while members cooperate to win, and the audience is thrilled by the changing scores. Spectators are only involved during the game, allowing them to focus on their tasks beforehand. Watching a match minimises their "in-game" time but still motivates them. Although running a football game is costly, minor sports like tug-of-war in primary schools have a similar effect. Pupils compete with minimal training, and their peers are captivated despite not participating. The cost is low, and it serves as a break from learning. This shows that people can be deeply engaged as an audience without participating daily, regardless of the game's complexity or cost. This addresses the goals of minimising learning curves and distractions while maximising learning time at a low cost and catering to diverse needs.

The next challenge lies in understanding how this works and linking learning with a game the audience does not play. Sports games can generally be categorised as competitive or collaborative, or both in group sports, as competition and collaboration serve as versatile tools for harnessing extrinsic and intrinsic motivational factors to engage players (Abuhamdeh & Csikszentmihalyi, 2009; Kong et al., 2012). This can be easily simulated in digital games. The audience's engagement, despite not playing, depends on their connection to the game. Once the connection is established, possession, ownership and sociopsychological factors exert their influence as motivators (Chou, 2014). In the football example, winning a match is the goal. Spectators align themselves with this goal through their affiliation with a team. This alignment can be cross-national. For example, many Chinese support Manchester United even though they are not British (Sullivan et al., 2022). When the football players are determined to kick the ball into the net, so are the spectators. In the tug-of-war example, pupils align themselves with their class's team and, even as spectators, feel as though they are playing the game. Betting can strengthen this bond by associating money with game outcomes, enhancing ownership and activating motivators like loss and avoidance (Chou, 2014). The audience is captivated by instant progression feedback, where every movement towards a goal heightens enthusiasm. This positive feedback from determined effort, seen in sports, can be applied to learning to engage and motivate learners continuously.

Observing sports reveals a strategy for engaging learners with digital games as an audience (AA). This minimises the learning curve and distractions while maximising learning time. Learners can use their scores to power up a character or team in a competitive or collaborative digital game. This bond activates motivators like possession, ownership, loss, and avoidance, making the audience eager to see their team win. Chou's Octalysis framework (2014) explains how these motivators drive engagement. Targeting game audiences instead of integrating game elements eliminates the need for subject-specific game development, reducing costs and allowing universal application across subjects, similar to how sports attract diverse spectators without tailoring events to specific interests.

3.3 The DGBL-AA Framework

The literature review, along with observations in the field of sports, inspires a Digital Game-based Learning as Audience (DGBL-AA) framework. That is, in real life, people don't need to participate in a game to be immersed in it. The same concept can be applied in DGBL. It can be described as follows:

- Subject-independent and progress visualisation only: The game should be detached from any subject and only used as a progress visualisation so it can be universal, potentially reduce development time and cost, and allow learners to only participate in the game as the audience to achieve the aim of minimising distraction and maximising learning time.
- Competition and collaboration: The game can be in a competitive or collaborative model or both, widely used as motivation vehicles. If designed properly, extrinsic motivators in games can activate intrinsic motivation (Birk et al., 2016).
- Connection and motivation: Learners can bond with an in-game character or team using their learning scores, which also power up their character or team. This connection activates motivational factors like possession and ownership, as well as game-related motivators such as loss avoidance, apex meaning, and social influence.
- Positive feedback and engagement: Motivation is not the same as engagement. Motivation can get people to start the task, but it doesn't necessarily mean people will stay with it. People need constant high-quality stimulation to be engaged (Saeed & Zyngier, 2012). Given that positive feedback is crucial for engagement, progression visualisation should foster a sense of achievement through determined effort, ensuring that even small advances feel rewarding, especially for slow learners.
- Short intervals: The longer the delay of positive feedback, the less engaged the learner will be. Therefore, frequent positive feedback is highly recommended (Juul, 2010). Since the learners can only experience the game after a learning period, a balance should be achieved between minimising distraction and maximising learning time (Schnotz, 2007).

This DGBL-AA setup modularises learning activities, games, and learners' motivations, generating a learning and stimulation cycle, motivating learners to become more attentive in lessons and stimulating their desire to learn more, resulting in efficient learning, as illustrated in Figure 1.

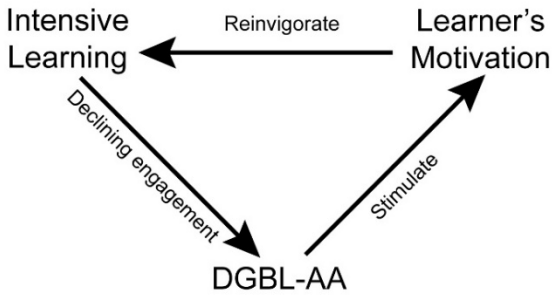

Figure 1: DGBL-AA efficient learning cycle

3.4 How the DGBL-AA Framework Achieves the DGBL-AA Goals

In summary, the DGBL-AA goals are achieved by:

- Goal 1 - Separating learning time from gaming time. Let learners focus on one thing at a time. Since learners don't need to understand the intricacies of a game and actively play it, this goal can be achieved. This is a process of modularisation. A game can be developed independently of a specific learning subject.
- Goal 2 - Bridging the learning outcomes with an engaging game to achieve the second goal. Engagement can be fostered by competitions and collaborations between in-game characters or teams that are associated with the learners.
- Goal 3 - Since the game acts like a plugin to a current learning activity, there is no need to spend money on a custom game for a learning subject, resulting in low cost.

4. Methodology

In 2023, several schools of pupils aged between 8 and 9 were invited to the University to explore computing technologies. This was an excellent opportunity to test the efficiency of the DGBL-AA framework. The main hypotheses explored were:

- Hypothesis 1: For a simple, focused learning activity, the addition of a game that offers additional intrinsic or extrinsic motivation will result in greater engagement as measured by recall tests (DGBL-AA).
- Hypothesis 2: In this setup, either competition or collaboration can lead to better learning achievement.

4.1 Participants

The first study aimed to test whether the DGBL-AA setup could engage participants and increase their scores. Therefore, employing a control group and an experimental group was ideal, as it allowed for a comparison between those who experienced the DGBL-AA setup and those who did not, ensuring the validity of the results.

In the first study, the pupils, 26 in total, from the first two schools formed a control group. They didn't experience the game and only participated in the shared learning activities. Twenty-eight pupils from another two schools formed the experimental groups to learn with the game. These 28 were split into two sub-groups. One learned in competition mode, and the other in collaboration mode.

4.2 Procedure

To avoid prerequisite knowledge causing inaccuracy in the data analysis, Big Data was chosen as the learning subject because it was not explicitly covered in the participants' curriculum (England Department for Education, 2023).

There were four phases in the whole learning journey. Each one consisted of a one-minute teaching video, six memory testing questions and a game with progress visualisation. The control group didn't experience the game.

An e-learning platform, Learnvoy, developed by UCLan, was used to host the videos and questions. The game was created as a plugin for the platform. It calls the platform's APIs to attain the participants' scores. The experimental groups observed how their scores powered the progress of their in-game characters in each phase.

Both quantitative and qualitative research methods were implemented. The quantitative data came from the participants' scores on answering memory testing questions, which served as a tool to judge attentiveness and engagement. The qualitative data was gathered using some subjective questions.

5. The Implementation of the DGBL-AA ramework

A Frogs game (game as audience) was created with the overall consideration of the participants, facilities, resources, and the DGBL-AA framework. Below, we describe how the Frogs game adheres to the guidelines outlined in the framework.

5.1 A Subject-Independent Game Used for Progress Visualisation Only

The Frogs game is not fixed to any learning subject. It can take learners' scores from learning activities to power up the in-game characters. Progress visualisation doesn't have to be delivered by a progress bar or map. Anything that conveys a sense of progress can be adopted. In the Frogs game, progression is presented as the distance between each frog and the castle (Figure 2).

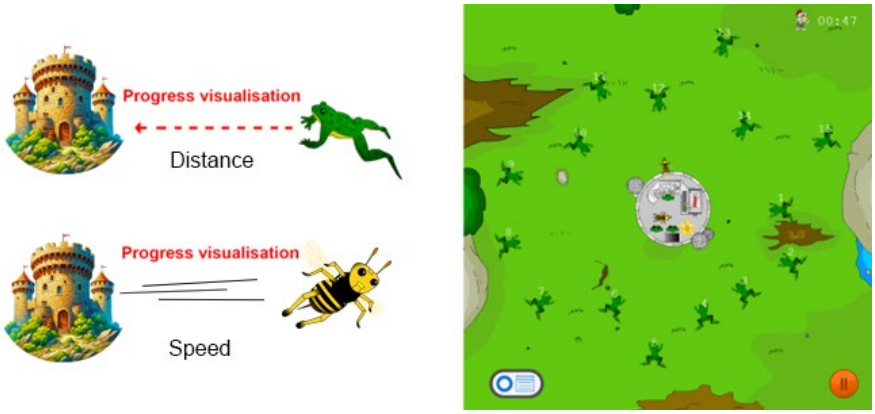

Figure 2: Progress visualisation in the Frogs game

5.2 Competition and Collaboration

In the Frogs game, the competition mode is built on the idea that the frogs compete to reach the castle. Therefore, each learner is associated with a frog. The speed of the missiles is predetermined to allow someone with a good score to reach the castle within the time limit. The closer a frog is to the castle, the closer the learner is to the target score.

In the collaboration mode, the idea is to build up the castle's resistance to the attack collectively. The resistance depends on the speed of its missiles. Based on this idea, the aggregated score from the whole group is used to determine the speed of the missiles. The progress visualisation is illustrated by how far the frogs can be pushed back within the time limit. The increasing speed of the missiles also contributes to the progress visualisation.

5.3 Connection and Motivation

As mentioned, the connection between the learners and the game is achieved by powering up the in-game characters with the learners' scores. The score increases whenever a learner answers a multi-choice question correctly. With the increment of the score, a frog hops faster in the competition mode, and the missile travels faster in the collaboration mode. This connection is like the betting mechanism in sports like horse racing and football matches, which activate some motivators, such as possession, loss, and avoidance (Chou, 2014).

Social influence is another powerful motivator (Chou, 2014). By running the learning activity and game in a class, learners are influenced by each other's advancement and enthusiasm, regardless of whether it is in competition or collaboration mode.

The game's story is crafted to trigger apex meaning (Chou, 2014). Based on the frog and princess tale narrates that the frog kingdom became excited after the story spread. When another princess was found sleeping due to laziness, a tide of frogs marched towards the castle. A prince, hearing of this, raced to rescue her but took time to arrive. Thus, the apex meaning is either kissing the princess to become a prince or keeping the frogs out of the castle until the prince arrives (Figure 3).

Figure 3: The background story of the Frogs game

5.4 Positive Feedback and Engagement

As explained in 3.2. Achievement through determined effort is a good form of positive feedback. In the competition mode of the Frogs game, getting a higher score to speed up the frog to resist the missile push is a determined effort. Since the score can only go up, the frog can constantly make progress. Witnessing the frog fight the missile and get closer and closer to the castle is designed to provide constant stimulation. In collaboration mode, as missile speed increases and the ability to push frogs further improves, the relief from repelling the relentless attacks gradually builds up gratification.

5.5 Short Intervals

The learning activity was divided into four phases to facilitate frequent positive feedback. In each phase, the participants watched a minute video about big data and then answered six multi-choice questions, and the game experience time was about one minute each. Each phase lasted for about eight minutes.

5.6 Evaluate if the Implementation Achieves the Goals

Thereby, the three DGBL-AA goals are achieved because:

- Goal 1 - The learning curve is minimised because of the simple rules which only need to be explained once. Distractions are also minimised due to the short game experience time, which is only one-eighth of the duration of a phase. Therefore, learning time is maximised.
- Goal 2 – Sections 5.2, 5.3, and 5.4 ensure that the game is well-designed with motivators and engages learners in continuous learning.
- Goal 3 – It took about one month to build the Frogs game, which can be used for any subject. Compared to a full-scale serious game for a subject, the development cost is very low.

6. Analysis and Findings

As outlined earlier, two studies were conducted to explore whether the DGBL-AA could engage learners and benefit efficient learning. All child participants were informed that their data would be used anonymously. Both quantitative and qualitative research methods were employed. This section will present the analysis and findings.

6.1 DGBL-AA Evaluation – Hypotheses 1 and 2

Hypotheses 1 and 2 were tested in a study reported in 2023, with the setup following the principles of DGBL-AA. The publication details the data collection methods, their justification, and the data collected (Xu et al., 2023). Here, we only provide a summary, as this is a follow-up paper. The recall test scores from the experimental group were significantly better than those from the control group, and both sub-groups, competition and collaboration, showed high levels of engagement, indicating that the setup enhanced the participants' engagement. T-tests were employed to check the significance of the statistics. The experimental groups: M = 12.36, SD = 2.38; the control group: M = 10.77, SD = 2.34; $t(52) = -2.423$, $p = .009$. However, despite higher average scores, statistical analysis revealed no significant difference in the recall test achievement between the competition and collaboration modes. The competitive mode: M = 12.93, SD = 2.55; the collaboration mode: M = 11.79, SD = 2.04; $t(22) = 1.262$, $p = .218$. A Progression Embodiment Graph (PEG) was included. Here is an updated version, which changes the "progression" axis to "perspective and actual progression" to explicitly include perspective progression (Figure 4).

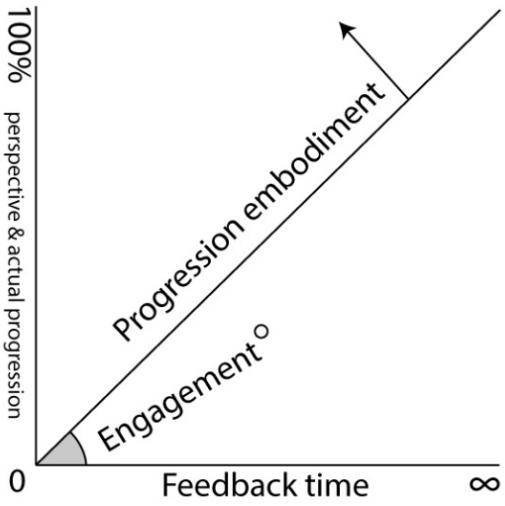

Figure 4: The second version of PEG (Progression Embodiment Graph)

7. Discussion

7.1 Interpretation of Results

The data from the experiments reveal insights into the effectiveness of the proposed framework. The engagement levels among learners using the DGBL-AA activities were notably higher than those without the gamification. This observation aligns with the hypothesis that motivational elements embedded in progress visualisation cater to stimulate learning, thereby sustaining interest and participation over time. Notably, the framework's emphasis on an efficient learning cycle, Intensive Learning – DGBL-AA – Motivation, appears to positively impact learners' ability to grasp and retain new information.

7.2 Limitations and Future Research

While the experiments provide valuable insights, they are not without limitations. First, only one game was created to evaluate the framework. More games with progress visualisation can be developed to further examine the framework. Potentially, these games can interact with each other. Eventually, a virtual world where people can observe to motivate their learning can be created if orchestrated meticulously. Besides maintaining motivation over extended periods, such as a semester, examining the efficacy of the framework with older students will be added to the list of studies. Also, the sample size and context of the study may limit the generalisation of the findings. Further study can seek answers to this issue.

8. Conclusion

The three DGBL-AA goals, the DGBL-AA framework, the DGBL-AA efficient learning cycle and the updated PEG were the products of the generalisation. This pioneering study offers promising evidence supporting the efficacy of the DGBL-AA framework and cycle for learning activity designs, particularly in improving learning outcomes and engaging students.

By incorporating motivational factors into progress visualisation, the framework has the potential to impact educational practice and learner success significantly. Our experiments demonstrate that by integrating this framework, educational institutions can significantly improve learning outcomes and student engagement. The increased attentiveness was confirmed.

However, this research is just the beginning. Future studies should aim to refine the framework, explore its applicability in various subjects and academic levels, investigate games with different progression visualisations, and long-term impacts on student achievement and motivation.

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