A QUALITATIVE STUDY OF PRACTITIONER PERSPECTIVES ON THE DESIGN AND DEVELOPMENT OF EFFECTIVE GAME-BASED LEARNING SOLUTIONS

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Abstract

This paper presents the findings of a study of Game-Based Learning (GBL) practitioners (N=12). The practitioners, who were a mix of academics, researchers and industry practitioners with experience of GBL research and / or implementation, were asked open questions in a survey about the effectiveness of GBL, the benefits that virtual reality (VR) bring to GBL, how the use of learning analytics dashboards (LADs) can help learner and educator, the mapping of learner interactions to taxonomies of learning, and whether universal design should be embedded at the heart of GBL. The questions also addressed the process by which GBL solutions are developed, with a focus on iterative prototyping and how GBL analytics can assist in the formative evaluation of a GBL solution when combined (triangulated) with other approaches (such as observations of learners playing a GBL solution). To assist the respondents, a case study was presented in the form of a game play video (of a VR-based GBL solution that teaches graph theory) with commentary by the GBL developer along with screenshots of learning analytics visualizations from a study of learners (N=20) carried out by the author.

A thematic analysis was carried out on the responses. On a question by question basis, meaning units were identified and categorized, and the categories were organised into themes. This led to several findings per question. The findings include: GBL is effective, but must be well designed; VR is an exciting, largely unexplored medium with many positive pedagogical benefits, but it has disadvantages such as cost and inaccessibility; LADs assist learners to be more autonomous and help with their executive functions, but they need to be carefully designed with actionable information and need to use visual aids to help comprehension; mapping learner interactions to a taxonomy (for the purpose of visualization) can support learners’ executive functions, such as assessing performance and progress, and setting goals – the gathering of learner interaction data has potential for automating the prediction of learner performance, which could lead to earlier intervention; an iterative approach to GBL development allows for greater inclusion of stakeholders, continuous improvement and more complex solutions – this agile approach in GBL development is under way and following the lead of other industries; using visualizations as part of formative evaluation can identify issues of usability, flow and balance, as well as measuring effectiveness; the practitioners agreed that universal design should be embedded at the heart of any model for GBL design and development, but were largely unaware of specific frameworks for universal design in education, such as the Universal Design for Learning (UDL) framework; when evaluating GBL solutions, a mixed methods approach was seen as best practice with triangulation then becoming possible to identify more complex issues.

The findings of the practitioner study will be of interest to all designers and developers of GBL solutions. They provide guidance on many aspects of modern GBL, such as the benefits of VR, the use of agile development processes, the integration of learning analytics, and mixed methods evaluation that allows for triangulation of findings from multiple datasets.

Keywords: game-based learning, learning analytics, virtual reality, agile development, mixed methods research, universal design for learning.

1 INTRODUCTION

This paper presents findings from a study of game-based learning (GBL) practitioners about their perspectives on how GBL solutions can be designed and developed to make them more effective. It builds on previously-published research by the authors into the effectiveness of a game that teaches the fundamentals of graph theory (hereafter known as the graph game) through the medium of virtual reality (VR), along with how the iterative model used to design and develop the graph game employs learning analytics and the universal design for learning (UDL) framework [1]–[3].
While a previous study on the graph game concentrated on how learners (N=20) interacted with the game and a learning analytics dashboard (LAD), the practitioner study examined what GBL practitioners thought about the approach used in the design and development of the game and the platform, which included an application programming interface (API) to record learner interactions in a central data repository. The reason for doing the studies in that order was to:

1. allow the learner study produce learning analytics and visualizations for the practitioners to consider and reflect upon;
2. have a case study demonstrating the iterative model (including mixed methods-based formative evaluation of prototypes) in action for the practitioners to consider and reflect upon.

2 BACKGROUND

GBL has potential as a learning tool to enhance a learner’s experience and outcomes when compared to traditional methods [4]–[9]. While some meta-analyses show that GBL is more effective than traditional instruction methods, others have shown differences that are not statistically significant [10]. There have also been questions about how compatible games are with deep learning, though regular feedback can make learning deeper [5]. GBL has been found to be effective in the sciences when games are conceptually well integrated [11]. A review of the literature, therefore, suggests that while GBL can be effective, it is usually when it has been well designed, such as including regular feedback and ensuring that game mechanics have the concepts being taught embedded within them rather than as an afterthought.

The Adaptive Model for Digital Game Based learning, introduced in [2] and refined in this paper, is an iterative model for the development of effective GBL solutions. Fig. 1 shows a high level diagram of the model. Fig. 2 expands on the analysis and design phase, which was influenced by GBL models, such as the 4DF (four-dimensional framework) model [12] and the LM-GM (learning mechanics – game mechanics) model [13], and taxonomies of learning, such as Biggs's SOLO taxonomy [14]. Learner interaction events (LIEs) are discrete observable learning events that occur in a game that can be stored as data points (via an API to a central data store). This could be evidence of learning, such as the completion of a challenge or an indication that content has been read, or gamification events, such as the award of a badge. The mapping of learning to LIEs is further discussed in [1].

![Figure 1. The Adaptive Model for Digital Game Based Learning (AMDGBL).](image-url)
Key to the AMDGBL are iteration and formative evaluation. Iteration involves continuous improvement of a prototype (using formative evaluation) up to deployment in a learning context and beyond (using summative evaluation). Formative evaluation in a GBL context can use several evaluation methods; in the AMDGBL, this includes an evaluation of a prototype universality using the UDL framework [15], its serious game mechanics (SGMs) [13], its balance (for example, by employing Schell’s lens of challenge [16, p.209]), its flow (such as Csikszentmihalyi’s three dimensions of experience [17], which was updated by Schell [16] to include a less linear flow), its motivational affordances (Csikszentmihalyi’s provides guidelines for creating intrinsically motivating activities [18], while Schell provides the lenses of motivation and novelty [16, pp.153,155], and its narrative (if present, one can analyse the narrative serious game mechanics (NGSMs) [19] in the game.)

In addition to an evaluation using the various models, frameworks and lenses listed, a study takes place to evaluate each prototype iteration. This involves a mixed methods approach involving observation of learners as they play (and learn), a think aloud protocol, a questionnaire, and data / learning analytics. Fig. 4 shows a sample visualization of learner performance, but other visualizations can include custom events, such as the time taken to master new game mechanics during a tutorial to identify usability or accessibility issues (which is discussed in [2] at length).
3 METHODOLOGY

3.1 Study Design

A number of practitioners in Ireland and the United Kingdom were identified using purposive sampling to ensure the participants were relevant to the research questions (this is a “strategic” approach as outlined by Bryman [20, p.415]). This meant approaching practitioners who had experience of research and/or implementation in the area of GBL. To be considered a candidate participant, the practitioner needed to have one or more of the following characteristics:

- The person has published a paper related to game-based learning;
- The person works as an educational technologist and has a knowledge of the current state-of-the-art in game-based learning;
- The person works as a consultant in the private sector developing game-based learning solutions.

Guest et al. [21] suggests that 12 participants in a qualitative study approaches saturation and this is supported by Boddy [22], who suggests that typically between 10 and 30 participants is enough for a homogeneous group (which the GBL research and implementation population is arguably likely to be). Therefore, 12 participants were recruited.

Prior to commencement of the main study, a trial demonstration was performed before an audience of people meeting the criteria outlined above. Questions were fielded from the audience and this helped identify topics to highlight during the subsequent demonstrations and the video that were part of the main study; this was particularly important for the recorded video because remote participants in the study were not in a position to ask questions and receive an immediate response.

The demonstration and video included:

- a recording of the graph game being played from start to finish, showing the lead author completing the challenges in the game (see Fig. 3 for a screenshot);
- a series of visualizations of learner performance (see Fig. 4 for a sample visualization);
- an overview of how mixed methods (including observations, a think aloud protocol, data analytics, and a questionnaire) were employed to formatively evaluate prototypes as part of the AMDGBL.

Figure 3. A graph rendered in virtual reality in the graph game.
Once the demonstration or video was complete, each participant completed an online questionnaire featuring eight open questions. The questions were based on the following eight areas of interest related to the VR-based graph game, the LAD (and the learning analytics platform it is built on) and the iterative model used to develop the graph game:

1. The effectiveness of GBL – if the practitioners consider GBL to be ineffective, it raises a question about the need for the game, platform and model in the first place.

2. The use of VR – a clear hypothesis was developed concerning the benefit of VR in terms of learner autonomy in particular, but there were other potential benefits to VR identified in the literature, such as kinaesthetic learning, the development of psychomotor skills, and the increased sense of presence (or immersion).

3. Learning analytics dashboards – central to the model is the use of LADs and the hypothesis that they will help learners to perform executive functions, such as goal setting and planning.

4. Mapping learning to a taxonomy to clearly visualize learning progression.

5. The agile, iterative approach to development with frequent prototyping involving key stakeholders.

6. The use of data / learning analytics for formative evaluation during development.

7. The embedding of the universal design for learning (UDL) framework in the model.

8. The mixed methods approach and triangulation of data to gain new insights or improve confidence in findings.

3.2 Content Analysis Method

The questionnaire textual data was analysed using thematic analysis as outlined by Graneheim and Lundman [23], which is widely cited and was based on a wide-ranging examination of literature on qualitative content analysis. The question responses were examined for both manifest content and latent content – the former being what is obvious and the latter what is inferred; there is a level of interpretation in both, but more with the latter. The content was searched for meaning units (words or

Figure 4. A visualization of a learner's performance during an in-game challenge.
phrases relating to a central meaning), condensed where necessary, and then the higher-order headings were abstracted – codes, categories and themes.

There is insufficient space in this paper for all of the codes, categories and themes that emerged from the content analysis. Table 1 shows the categories and themes that emerged from question 1 about the effectiveness of GBL (including all of the codes from which the categories emerged would, again, take too much space).

<table>
<thead>
<tr>
<th>Theme</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of Good Design</td>
<td>Effective Design, Conceptual Integration, Accessibility</td>
</tr>
<tr>
<td>Positive Effect on Engagement</td>
<td>Engagement, Motivation</td>
</tr>
<tr>
<td>Pedagogical Benefits</td>
<td>Learning, Cognitive Benefits, Transformative Effect, Collaboration, Digital Literacy</td>
</tr>
<tr>
<td>Embedding in Curriculum</td>
<td>Complementary, Under-utilized, Non-GBL Games</td>
</tr>
<tr>
<td>Lack of Uptake</td>
<td>Lack of Uptake, Disadvantages</td>
</tr>
</tbody>
</table>

Using the themes and categories as a guide, the detailed findings from the same question were:

1. GBL is effective from a learning, engagement and motivational perspective when designed well.
2. This requires the integration of several aspects of good game design, such as effective mechanics and narrative, along with pedagogical aspects, such as well-designed learning for specific objectives, and the integration of the wider curriculum into a game.
3. This can lead to cognitive benefits such as improved knowledge retention and learning transfer.
4. However, GBL developers must be equipped with the right skills and experience (which they often lack), otherwise the resulting game could be either ineffective or lacking fun.
5. It facilitates situated learning where the relevance of learning can be highlighted.
6. One respondent went as far as to say that GBL can have a lasting transformative effect on the learner.
7. The benefits can extend beyond the game’s content with improvements to digital literacy and team work (so called “soft skills”).
8. Another respondent pointed to the learning potential of non-GBL games, such as ones designed primarily for entertainment, in terms of motor and soft skills.
9. GBL is under-utilized and can be complementary to traditional teaching and learning methods, though according to one respondent should not be a replacement for traditional methods (“face to face and contact time”).
10. There are, though, several disadvantages to GBL that affect its uptake by educators: because it must be well-designed and proven to be effective, it follows that there are examples of ineffective GBL (which does not often get highlighted in the literature on GBL effectiveness); it can be expensive and time-consuming to develop. There is also a healthy skepticism about GBL on the part of educators that affects adoption.

These findings were then summarised as follows:

GBL is effective in terms of learning, engagement and motivation, but it must be designed well to integrate game and pedagogical components. GBL is under-utilized and can complement traditional methods of teaching and learning, though not usually as a direct replacement. However, it has not always been successful (which is a reason for ensuring good design practices) and can be expensive and time-consuming to develop.

4 FINDINGS

Section 3.2 outlined the content analysis method employed and the full findings for question 1 (the eight questions are listed is Section 3.1). The remaining summarized findings for questions 2 to 8 were:
VR is an exciting medium that is as yet largely unexplored in a learning context. It has many positive pedagogical benefits, including a high level of engagement and novelty, the use and development of psychomotor skills, and support for different learning preferences, including the visual or active learner. Its immersiveness and realism can increase the relevance of what is presented. It provides a risk-free environment that supports exploration. It can increase focus. It can improve learner choice. However, there are disadvantages such as cost and inaccessibility to some.

Learning analytics dashboards help learners to be more autonomous and help with executive functions such as goal setting and planning. They are of increasing importance to educators because they can identify learners in need of intervention. LADs require careful design because they can end up being under-utilized and educators will need to be educated on how to interpret the visualizations presented—the information presented needs to be concise and actionable. They need to be simple enough for the great majority of students, so metaphors like traffic lights can help comprehension.

The mapping and visualization of learner progression can support learners’ executive functions, such as assessing performance and progress, and setting goals for work to do. It can support formative and summative evaluation. It can support cutting edge features, such as predicting learner performance and this can be automated because of the learner interaction data.

The iterative / agile approach of the AMDGBL is process-oriented with an emphasis on continuous improvement of the GBL solution under development. The iterative process allows for complex solutions to be developed. It is an inclusive process that ensures all stakeholders understand requirements and are kept up to date on progress. The move to iterative and agile methods is well underway and is only following the lead of other industries.

Using visualizations as part of formative evaluation can identify issues of usability, flow and balance, as well as measuring effectiveness. Issues can be diagnosed, but further analysis is required to provide a solution to the issues. The approach can be seen as best practice and is only catching up on similar approaches to the evaluation of other software.

The GBL practitioners agreed that universal design is important and should be embedded (rather than just added on at the end) in any model or framework for GBL development. Practitioners are aware of the benefits (and challenges of providing them), such as improved accessibility and learner autonomy. However, it is clear that the specifics of universal design and in particular the UDL framework are largely unknown to many practitioners.

Employing a mixed methods approach is seen as best practice, though it is noted that the inclusion of quantitative methods based on gameplay data alongside qualitative methods requires more expertise and adds more expense. Through triangulation, it is possible to identify more complex issues. Evaluation could be streamlined with the automation of analytics.

5 CONCLUSION

5.1 Summary
A purposive sample of twelve GBL practitioners either participated in-person in a demonstration of the VR game or remotely watched video of gameplay with commentary by the researcher. They were also shown visualizations that would be available to learners and/or educators. This provided context for the online questionnaire that followed. Open questions asked about the effectiveness of GBL and VR, the benefits of learning analytics dashboards, the mapping of learning to a taxonomy to visualize learning paths, the use of an agile, iterative approach to GBL design and development, formative evaluation and how it can identify issues through analysis of gameplay data, embedding the UDL framework at the heart of the AMDGBL, and the use of multiple methods to triangulate data to improve confidence or gain new insights. A thematic analysis was performed on the response textual data. Numerous findings were made under each question and these were summarised.

5.2 Discussion
The practitioner responses positively supported the approach of the AMDGBL and highlighted the importance of designing GBL solutions effectively to integrate learning with gameplay, which is what the AMDGBL was designed to do.
The AMDGBL’s iterative approach, featuring a formative evaluation using data / learning analytics, was endorsed by the practitioners and was seen by some as a way for the GBL research community to catch up with industry best practice (particularly the commercial games industry).

The findings of the practitioner study will be of interest to all designers and developers of GBL solutions. They provide guidance on many aspects of modern GBL, such as the benefits of VR, the use of agile development processes, the integration of learning analytics, and mixed methods evaluation that allows for triangulation of findings from multiple datasets.

REFERENCES


