Toward Performance Prediction Using In-Game Measures

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***Abstract*—The efficacy of a learning process is influenced by the quality of teaching, learning support and environment. This requires effort in tracking how students learn. This paper explores the use serious games in order to help understand the learning process, where interaction data during a play-learn session can be captured. The focus is on the use of in-game data, analyzed using Learning Analytics techniques, and discusses the potential of such an approach to predict learners' performance. Gameplay data were collected from various play-learn sessions based on a First Aid Game. Results indicate that in-game measures can help to understand students' progress and predict their performance, providing opportunities for individual support to be provided to learners.**
Keywords—serious games; performance prediction; user studies; learning analytics; game-based learning

I. Introduction

The challenge of delivering learning experiences is often increased with the size of classrooms and online learning communities. Serious Games (SGs), defined as game technologies applied in non-leisure contexts, are increasingly recognized for their potential to support teaching and learning, and have been used to motivate students [1]. Research is essential not only to gain a deeper insight into how the students are playing but also to deliver a comprehensive and intelligent learning framework that facilitates better understanding of learners' knowledge, effective assessment of their progress and continuous evaluation of learning environments.

Games are a fertile ground for leveraging such analysis; opening up new forms of game-based stealth assessment techniques. In line with the findings from the Horizon 2013 report [2], this paper aims to explore the potential for games and learning analytics (LA) towards scaffolding teaching and learning experiences.

The main focus of this paper is to evaluate whether meaningful data can be captured using in-game measures and whether some forms of prediction can be carried out with regards to a learner's performance. SGs and LA are introduced in sections II and III, followed by a description of our study method and materials in section IV. The results, discussions and conclusions are presented in sections V and VI.

II. Serious Games (SGs)

JRC Scientific and Technical Report [3] emphasizes that the future competitiveness of the EU Video Games Software Industry capitalizes on the fact that the majority of the future population will be digital natives. The power of games to immerse and motivate [4, 5] and to change perceptions have created a more positive approach to games and new game genres. More use of games in contexts such as learning and training [6] are transforming everyday lives, and multiplayer and social games communities are changing social interactions, leading to greater capabilities for social learning, interactions and importantly more fun in everyday contexts [7]. The main strengths of SG applications may be generalized as being in the areas of communication, visual expression of information, collaboration mechanisms, interactivity and entertainment [8].

Empirical studies can serve as benchmarks for establishing the scientific validity in terms of the efficacy of using games to motivate learning and achieve learning outcomes. For example, the first pragmatic controlled trial showed how game-based approaches were found to be more effective than traditional learning in triage training [9], while Kato et al. [10] showed how game-based approaches in Re-Mission promotes medication adherence in children with cancer. And recently, Arnab et al. [11] demonstrated that a game-based learning platform when deployed within a classroom setting promotes knowledge transfer and encourages communal discourse on sensitive issues.

These early studies have highlighted the ways in which game-based learning approaches can be used [9, 11]. 'Game science' as it is coming to be called, is looking at new ways to map against human experiences, and big data and LA are potential tools for allowing us to do this.

III. Learning Analytics (LA) and games

LA is an emerging field of Technology-Enhanced Learning, related with research areas such as big data, web analytics, educational data and recommender systems [12, 15, 16]. The common denominator of these areas is in relation to ways of collecting large amount of detailed data in order to find, analyze and present different patterns [13]. Norris et al [14] emphasize the use of analytics in terms of measuring, improving and comparing the performance of individuals, not just to discern and enhance learning experiences but also to facilitate better performance and outcomes through statistical measures. There are few LA tools that capture variations of data on what students do in order to learn. According to Siemens [17], this is mainly because LA-specific approaches are at their infancy and require further research.

Most games lack an appropriate assessment system to generate rigorous student results. While games promise to teach in innovative ways, the assessment of their effectiveness tends to gravitate back to written examinations or debriefing sessions [18]. This has caused an increasing gap between the purportedly deep learning that can be conveyed by educational games and the shallow techniques that are used to assess learners' performance at present.

Different solutions have been proposed to fill this gap, including using the games themselves to assess the performance. The field of implicit in-game evaluation (also called stealth assessment [19]) offers rich opportunities: since games are highly interactive, they can produce a great amount of data on how the user is playing.

Predicting performance via such a technique will assist teachers to address concerns prior to the actual assessment of the students. Predictive models and patterns can be correlated in the analyzed data based on specific metrics, which can be used to design actionable solutions to overcome the weakness of the teaching and learning strategy and resource allocation on the institutional level. For example, Ketamo and Multisilta [20] studied the relation between learning outcomes, speed of interaction and nature of misunderstandings to predict an optimal learning zone.

IV. METHOD AND MATERIAL

Meaningful interactions within a game are core to an effective play-learn experience. Meaningful in this case refers to interaction and engagement with contents that result in learning. In this case study we implemented an existing framework that facilitates these tasks. Building on top of former technical validation studies [21, 22], we aimed to examine the potential for predicting performance via in-game measures.

A. GLEANER

The GLEANER framework (fig. 1) is developed under the EU-Funded Games and Learning (GALA) project as a response to the emerging field of LA. The framework comprises both an abstract framework and an implementation to support the LA approach applied to educational videogames and LMSs [22].

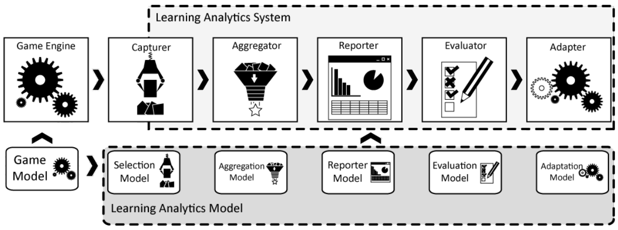

Fig. 1. GLEANER Framework main components and relationship with the game engine.

B. Game description

As a case study a First Aid Game was used, originally developed to teach Cardiopulmonary Resuscitation (CPR). The game was selected because it had already been tested and validated with a large student population [23]. The game has 3 photo-based scenarios: *chest pain*, *choking* and *unconsciousness*. Players had to make critical decisions responding to the scenarios (fig. 2). The point and click gameplay allows players to select options they feel as the best course of action. A rapid feedback loop allows players to understand the consequence of their choices.

Fig. 2. Example scenario and decision options

C. Study methods

The case study included the capturing of in-game traces and LA techniques to compute an in-game score for each student. The objectives of the study are presented below:

- To find out whether there is any difference in the players' knowledge of first aid techniques before and after playing the game.
- To find out whether there is a correlation between in-game scores and post-game scores of knowledge pertaining to first aid.
- To determine if the in-game can be used to predict the post-game scores.

The research made use of pre and post-game questionnaires completed by the participants to assess knowledge of first aid techniques. Play traces were captured during game play, and these traces were used to compute an in-game score.

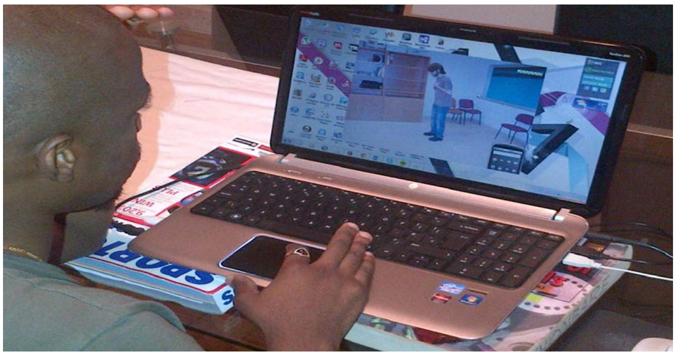

Fig. 3. A player interacting with the game

A *t* test was carried out to determine whether there was a significant difference in the student scores. The null and alternate hypotheses used are:

H0: There is no significant difference between the pre-game and post-game mean scores.

HA: There is a significant difference between the pre-game and post-game mean scores.

The next step of the analysis was to evaluate whether there was a correlation between the students' in-game and the post-game scores. This early work considered the in-game scores as the average score of the student from all 3 scenarios. The final step was to assess whether the new predicted scores could forecast the post scores and this was done using linear regression.

V. RESULTS

The experiment was carried out with 50 students at a higher education institution (Coventry University, UK). Each session took approximately 30 minutes to complete. During the analysis, incomplete data from 22 participants were discarded. Fig. 4 summarizes the pre and post game scores of the remaining 28 participants. Fig. 5 illustrates the scatter diagram of the in-game and post-game scores.

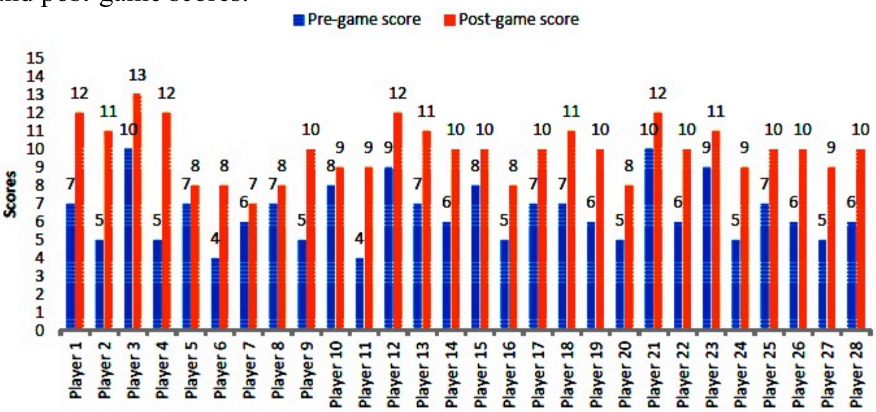

Fig. 4. Pre and post test scores comparison

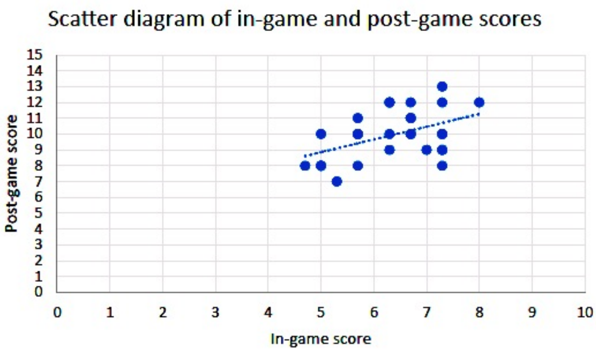

Fig. 5. Scatter diagram of in-game vs. post-game scores

From the t-Test the P (T<=t) two-tail value is 2.11 x 10^{-12} (table 1). This value is < 0.05 therefore there is a very significant difference and alternative hypothesis can be accepted. The null hypothesis is rejected.

TABLE I. T-TEST – PAIRING 2 SAMPLE FOR MEANS

	Pre-game score	Post-game score
Mean	6.5	9.928571429
Variance	2.703703704	2.291005291
Observations	28	28
Pearson Correlation	0.550611612	
Hypothesized Mean Difference	0	
df	27	
t Stat	-12.08421156	
P(T<=t) one-tail	1.05719E-12	
t Critical one-tail	1.703288446	
P(T<=t) two-tail	2.11438E-12	
t Critical two-tail	2.051830516	

Regarding the correlation between the post-game scores and the predictive in-game scores, Pearson's correlation r should be between +1 and −1 inclusive, where 1 is total positive correlation, 0 is no correlation, and −1 is negative correlation. The correlation coefficient, r in this analysis is 0.464923. This suggests that there is a moderate positive correlation between the in-game scores and the post-game test scores. Fig. 6 shows the predicted post-game versus actual post-game score plot.

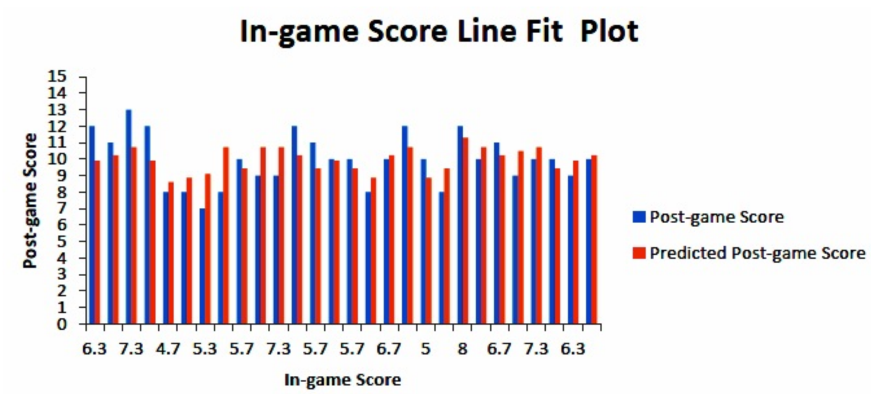

Fig. 6. Predicted post-game – in-game plot

This data was also used for a regression analysis to determine if it can be used for prediction. The predictive R2 value is 0.2161533 (between 1 and -1). The positive value indicates that it has the potential to be a predictive model. The R squared value suggests that it is a good predictive model. From the average score of students pre-game and post-game was 6.5 and 9.9 respectively. The t test showed that there is a significant difference in pre and post game knowledge. There was a moderate positive correlation between the in-game scores and the post-game scores which also supports the claim that students learn from the game. There is also a correlation found between the clustered scores and the post-game scores.

VI. Discussions and conclusions

This case study demonstrates that there is a significance increase between knowledge of appropriate first aid techniques before and after playing the game. There was also a moderate positive correlation between the in-game scores and the post-game scores which also demonstrates that in-game measures can be used to evaluate knowledge transfer. There is a strong correlation found between the clustered in-game scores and the post-game scores.

Based on the regression analysis, using in-game measures such as the in-game scores has the potential to aid prediction of the learners' performance. In-game measures have the potential to aid assessment of learners and to predict their gain of knowledge. More studies however are required for the complete set of play traces in order to understand the progress in knowledge and the interaction behavior during game play. Not only that the efficacy of the game can be measured in this way, the performance of the learners/players during game play can be evaluated and correlated with the post-game evaluation (game scores, player feedback). This will allow us to evaluate if the game contributes to students' learning and if it does, how it contributes to learning and to what extent.

It is also important to obtain analysis models that are able to provide reliable and concrete assessment results from the captured data, as well as models focused on spotting games weakness and/or learners' weaknesses and strengths during the learning process, which traditional assessment approaches (paper based, score based) do not support. Other analyses will include determining if there is any way to predict how a student would perform in a test based on interactions with the game.

Acknowledgment

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