

Measurement of Self-Efficacy in Game-based E-learning through Interaction with Non-Player Characters

Ioana Ghergulescu, Arghir-Nicolae Moldovan and Cristina Hava Muntean
School of Computing
National College of Ireland
Mayor Street, IFSC, Dublin 1, Ireland
ioana.ghergulescu@ncirl.ie; amoldovan@student.ncirl.ie; cristina.muntean@ncirl.ie

Abstract: This paper proposes a novel method for measuring learner's self-efficacy, an important indicator of learner's motivation, in game based e-learning through the interaction of the player with non-player characters. A subjective case study was conducted in order to evaluate the benefits of the proposed method. The results have shown that the player's self-efficacy changes in time during the game-play. Therefore, it is important to measure it regularly in order to enable maintaining the player motivated during the game-play through game adaptation.

Introduction

E-learning and in particular game-based e-learning has seen much growth recently, with the increasing adoption of digital technologies and of video games in order to facilitate and improve the learning process. While video games present the potential for creating engaging learning experiences, maintaining the learners motivated during the game-play continues to represent a big challenge for game-based e-learning (Ghergulescu & Muntean, 2012a, 2012b; Hwang & Wu, 2012).

With regard to games, self-efficacy is an important motivational factor in the gaming activity. Players who believe more in their competences will invest more energy and effort, will be more interested and perseverant in completing the game and less likely to withdraw (Klimmt & Hartmann, 2006). Therefore, players with higher self-efficacy are more motivated and more likely to achieve the learning outcomes. According to Bandura's self-efficacy theory, self-efficacy represents people's beliefs in their capabilities to execute a task or an activity at a certain level of performance, with this belief underlying human motivation (Bandura, 2010). Self-efficacy influences people's actions and beliefs, as well as their commitment, perseverance and effort in completing an activity.

The measurement and the assessment of self-efficacy in game-based e-learning is not a trivial task. Self-efficacy measurement through questionnaires is not feasible in game-based e-learning, as answering the questionnaire would require game-play interruption (Ghergulescu & Muntean, 2010). The interruption in turn can be a source of frustration, and can negatively impact on the learners' game-playing experience, their motivation and eventually their learning outcomes.

In this context, this paper proposes a novel Non-player character Self-Efficacy Measurement method (NPC-SEM), for measuring the players' self-efficacy during the game-play. This is done by embedding questions in the dialogs between the player and non-player characters. Non-player characters are characters controlled by the game that can be guides, competitors, evaluators, neutral characters, etc.

After a background overview on self-efficacy measurement in game-based e-learning, the remaining of this paper describes the proposed NPC-SEM method, and presents the methodology and results of the subjective case-study.

Self-efficacy in game-based learning

According to Bandura's self-efficacy theory of motivation (Bandura, 1994), a person must have beliefs that (s)/he is capable of solving, executing and pursuing a task. Self-efficacy represents the person's beliefs, and self-perception of their capabilities of executing the task at a certain level of performance. It influences people actions and beliefs (Bandura, 1994).

Bandura has also provided guidelines for measuring the self-efficacy and for creating scales depending on different purposes. It is important for self-efficacy to be measured in terms of perceived capability, which is in terms

of “can do”, rather than “will do” (Bandura, 2006). The author suggested a 100-point scale, ranging in 10 units-intervals, from 0 - “Cannot do at all”, through 50 - “Moderately certain can do”, to 100 - “Highly certain can do”. A simpler scale can be used such as for example a 10-level, 7-level or 5-level scale, with the condition to retain the same structure (from “Cannot do at all”, through “Moderately certain can do”, to “Highly certain can do”). Figure 1 illustrates a 7-level scale for self-efficacy measurement that follows Badura’s guidelines and other research studies (Ghergulescu & Muntean, 2011; Lahart, Kelly, & Tangney, 2009).

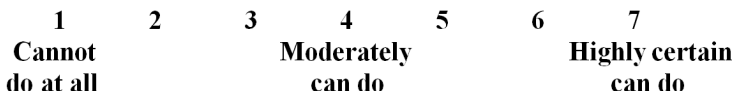


Figure 1: Seven-level scale used for player’s self-efficacy assessment.

Several research studies have addressed self-efficacy in measurement and assessment in game-based e-learning. McQuiggan et al. (2007) have measured player/learner self-efficacy while learning by playing in a game-based e-learning environment and solving genetics problems. Learner’s self-efficacy was measured at the beginning, during and at the end of the experiment. Based on the participants’ self-reports and psychological reaction, the authors made a self-efficacy prediction model.

Young et al. (2009) have investigated players’ self-efficacy while playing 2D and 3D educational games related to Earth science or games based on life science using 7th and 8th grade students (N = 276). Self-efficacy was measured after the player completed the game. The results have shown a statistically significant difference in self-efficacy between male and female participants from the 7th grade.

Meluso, Zheng, Spires, & Lester (2012) have studied the effect of game type (single game type vs. collaborative game type) on players’ science self-efficacy. The results have shown no difference between the two game types in terms of science self-efficacy. Self-efficacy was assessed before and after the participants played the game.

Brusso, Orvis, Bauer, & Tekleab (2012) have investigated interactions among self-efficacy, goal orientation and unrealistic goal setting on video game-based training performance. Self-efficacy was assessed using 5-point scale questionnaire items. The results have shown that a large discrepancy between the goals set by the players early in the game and their actual performance negatively impacting the subsequent training. However, self-efficacy together with performance-avoid goal orientation were shown to moderate the impact of the discrepancy, thus it is important to enhance players’ self-efficacy and help them set realistic goals in order to optimise the video game-based training.

Non-player character Self-Efficacy Measurement method (NPC-SEM)

As player’s self-efficacy like other user judgments can change over time, it is important to account for changes in the player’s self-efficacy during the game-play. This is normally done by asking the player to complete an out-of-game questionnaire while he/she plays the game. However, this approach is not feasible as it requires interrupting the game-play in order to answer the questionnaire. Interrupting the game-play in turn disturbs the player as it breaks the game flow. Flow represents an optimal state of enjoyment and concentration (Csikszentmihalyi, 2000), which translated to gaming involves the player being completely absorbed in the game-playing activity.

Therefore, in order to be able to measure the player’s self-efficacy during the game-play with minimum impact on the game flow, this paper proposes the Non-Player Character-based Self-Efficacy Measurement method (NPC-SEM). In-game player’s self-efficacy is measured by embedding a self-efficacy related question into player’s conversations with non-player characters, and recording the provided answer. During the conversation, a non-player character asks the player to rate their confidence in their ability to execute a particular task from the game. The same 7-point scale presented in Figure 1 is used.

Following Badura’s recommendations, to measure the self-efficacy in terms of “can do”, rather than “will do” (Bandura, 2006), NPC-SEM uses the following template for the self-efficacy measurement question:

“[Player name in the game], can you tell me how confident you are that you can do [task name] (on a 1 to 7 scale)?”

After the interrogative question is presented to the player, a 7-point scale (i.e., 1-“Cannot do at all”, 4-“Moderate can do”, 7- “Highly certain can do”), is displayed in order to obtain the player’s answer. The self-efficacy question has to be integrated into an existing conversation between the player and a non-player character in order to minimise the game flow disturbance. This can be done during the game creation or if the game can be edited afterwards by the game evaluator.

Case Study

An experimental case study was made in order to evaluate how the player's self-efficacy changes in time, and the utility of the proposed NPC-SEM method for measuring the player's self-efficacy during the game-play. While traditional out-of-game questionnaire-based methods (Pareto, Arvemo, Dahl, Haake, & Gulz, 2011), could also be used for measuring the player's self-efficacy more often by interrupting the game-play, NPC-SEM has the benefit that it enables automatic in-game self-efficacy measurement without interrupting the game-play. The player self-efficacy was measured at the beginning of the game, during the game-play and after the game.

Participants

Data collected from 55 participants was analysed. The participants age ranged from 18 to 55 years old ($M = 27$, $SD = 7$). The participants were of different nationalities, with both native and non-native English speakers. They had different occupations such as undergraduate students, postgraduate students and professionals.

Fire Protocol Game

Fire Protocol (Moreno-Ger, 2012) is a first-person game that aims to teach the fire safety evacuation protocol from a practical perspective. During the game, the player takes the role of Pablo, a member of the Faculty of Informatics from Complutense University of Madrid. The player has to answer the phone, and since he is new in the university he is instructed to learn about the evacuation procedure during a fire, by reading the protocol book placed on his desk. After that he has to answer the phone again, this time being informed to check for fire as the alarm was triggered in office 411, and to start the evacuation procedure if necessary.

After checking for fire, the player has to activate the alarm and then to check the teacher offices in his building wing. In office 414, the player meets Balta, the non-player character with whom he has a conversation informing him that there is a fire in office 411 and he has to leave the building immediately. Once the player has checked all the four offices he can proceed to leave the building. In order to successfully complete the evacuation procedure the player has to do all the tasks, as well as to maintain his calm during the conversation and to leave the building on stairs rather than taking the elevator.

Methods and Procedure

In order to determine if the player's self-efficacy changes in time during the game-play, the participants' self-efficacy was assessed through a questionnaire at three different moments of time during the experiment: before, during and after playing the educational game. A 7-point response scale was used, ranging from 1 - "Cannot do at all", through 4 - "Moderate can do", to 7 - "Highly certain can do".

The initial and post-game self-efficacy were assessed through specific questions that were answered by the participants in paper and pencil format. The initial self-efficacy was assessed using the question: "How confident are you that you can finish the game that you will play in this testing session?". The post-game self-efficacy was assessed using the questionnaire item: How confident are you that you can finish other levels of the game 'Fire Protocol'?. The participants' self-efficacy during the game-play was assessed by embedding a questionnaire item into the conversation between the player (i.e., Pablo) and the non-player character (NPC) (i.e., Balta).

Figure 2 presents the game's scenes where the NPC asks the player how confident he is that he can finish the evacuation protocol task ("Pablo, can you tell me how confident are you that you can finish the evacuation protocol (on a 1 to 7 scale)?"). Since the game limits to five the maximum number of answer choices that can be displayed at a time, the player needs to click first on "More" in order to get the levels 5 to 7 displayed.



Figure 2: Integration of the self-efficacy assessment question in the conversation with the non-player character for the Fire Protocol game.

Results

Figure 3 presents the averaged self-efficacy measurements across all 55 participants at the three moments of time (before, during and after the game-play), as well as the 95% confidence intervals. The average self-efficacy before the game-play (initial) was 5.4 (SD = 1.1), the average self-efficacy during the second part of the game (in-game) was 5.1 (SD = 1.8), while the average self-efficacy after the game (post) was 5.8 (SD = 1.4).

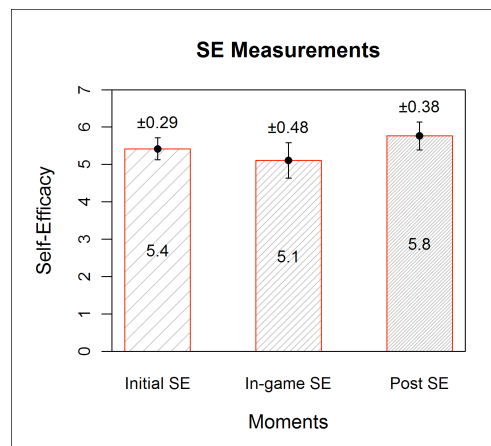


Figure 3: Average self-efficacy values before, during and after the game.

Before choosing the statistical procedure and proceeding to analyse if there are statistically significant differences between the three self-efficacy measurements, a testing for normality is conducted in order to determine if non-parametric or parametric statistical tests should be used. Testing univariate data for normality can be done through a combination of descriptive methods such as comparing the histogram of sample data to a normal probability curve or comparing the sample data against the quantiles of a normal probability distribution (Thode, 2002). A number of statistical procedures to test the sample data against the null hypothesis that this is normal are also available. Shapiro-Wilk and Anderson-Darling normality tests in particular were shown to have a very good performance across different distributions and sample sizes (Razali & Wah, 2011). In order to test for self-efficacy normality both Shapiro-Wilk and Anderson-Darling tests were conducted.

Figure 4 presents the histograms of the three self-efficacy measurements, as well as the normal Q-Q plots. Normal Q-Q plots compare the probability distribution of the data to a normal distribution. The linearity of the points on the Q-Q plots suggests that the data is normally distributed. As it can be noted from the figure, the data for the three self-efficacy measurements does not follow a normal distribution. This is further confirmed by the results of the Shapiro-Wilk and Anderson-Darling normality tests, which indicate with a 99.9% confidence level ($p < 0.001$) that the data sets are not normally distributed (see Table 1).

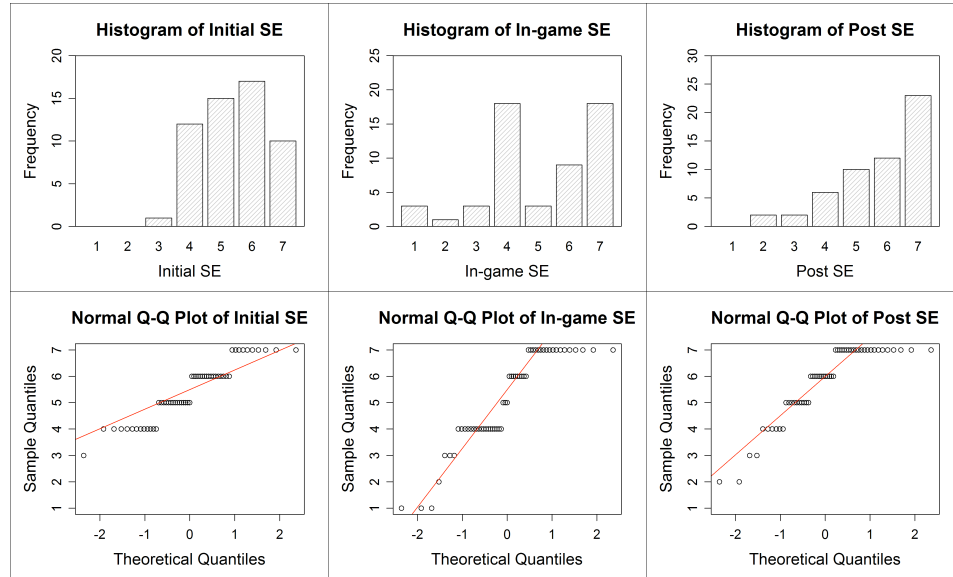


Figure 4: Histograms and normal Q-Q plots for the three self-efficacy measurements.

Table 1: Results of the Shapiro-Wilk and Anderson-Darling normality tests for the three self-efficacy measurements.

SE Measurements	Shapiro-Wilk test	Anderson-Darling test
Initial SE	W = 0.8977, $p = 2.071e-04^{***}$	A = 2.2155, $p = 1.073e-05^{***}$
In-game SE	W = 0.8571, $p = 1.081e-05^{***}$	A = 2.9017, $p = 2.158e-07^{***}$
Post SE	W = 0.8264, $p = 1.547e-06^{***}$	A = 3.3848, $p = 1.394e-08^{***}$

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Therefore, a non-parametric Friedman test equivalent to repeated measures ANOVA was conducted in order to assess if there is a statistically significant difference between the three self-efficacy measurements. The results of the Friedman test presented in Table 2, indicate with 95% confidence that there is a difference between the three self-efficacy measurements ($p < 0.05$ significance level). Following on these results, a non-parametric Wilcoxon-Mann-Whitney test equivalent to t-test was performed between every two self-efficacy measurements in order to see where the differences occur. The results (see Table 2), indicate with 90% confidence ($p < 0.1$) that there is a statistically significant difference between the initial and in-game self-efficacy measurements, and with 95% confidence ($p < 0.05$) that there are statistically significant differences between the initial and post-game, and between in-game and post-game self-efficacy measurements and between in-game and post-game self-efficacy measurements.

Table 2: Results of the Friedman and Wilcoxon-Mann-Whitney non-parametric tests for self-efficacy differences.

SE Measurements	Friedman test results
Initial SE vs. In-game SE vs. Post SE	Friedman chi-squared = 7.7162, $df = 2$, $p = 0.0211^*$
SE Measurements	Wilcoxon-Mann-Whitney test results
Initial SE vs. In-game SE	U = 969, $p = 0.0962$.
Initial SE vs. Post SE	U = 134.5, $p = 0.0382^*$
In-game SE vs. Post SE	U = 173, $p = 0.0115^*$

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Conclusion and Future Work

This paper presented a novel methodology for assessing player self-efficacy in game-based e-learning through non-player characters: NPC-SEM. Furthermore, this paper presented the results from a feasibility case study with 55 participants. The results confirmed that player's self-efficacy can change over the course of the game-play, and thus that it is important to be able to measure it at different moments of time. The proposed NPC-SEM method enables self-efficacy measurement during the game-play by embedding a self-efficacy assessment question in the conversation between player and non-player characters. Measuring self-efficacy more often can be done easily by embedding the questions in more conversations over the course of the game.

Additional research work is currently being conducted in order to study how disturbing is the proposed NPC-SEM method as compared to traditional questionnaire-based methods. Preliminary results show that the proposed method is less disturbing in terms of frustration measured using an EEG headset. These results will be presented in a different research paper.

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