

Educational Story-Based Game for Capturing the Learner's Personality

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Abstract: In recent years with the help of digital games there is an increasing interest in creating Serious Games for learning through play. With the help of machine learning algorithms, an educational serious game can be used, not only to assist the learner in his/her studies, but also to extract insights about the learner's personality. In game-based learning we take into account that the student behaves differently according to his/her individual characteristics while learning by playing. The most used method to model the learner's personality is the self-report using questionnaires. The drawback of this approach is that the learner may not assess himself correctly or his/her answers' may be biased towards the more socially acceptable responses rather than being truthful. In this paper, we explore the idea of having an alternative method of learning a person's personality model and thus to better create interactive and engaging methods to assist learners in their studies. A story-based game with gamified learning elements was created for helping the learners study and evaluate their knowledge in the programming language C. The students learn by evaluating code snippets and depending on their response the game would give constructive feedback. At the same time students' in-game behavior is captured and thus their personality traits could be determined. For modeling the learner's personality we used the Five-Factor Model (OCEAN), a taxonomy of five personality traits (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism), each of which combines many personality characteristics. To evaluate the efficiency of the proposed serious game, we gathered data from 107 first year Computer Science students from the University of Macedonia. The students played the game and filled in the Big Five Inventory (BFI) questionnaire to capture their OCEAN traits. The BFI questionnaire was used as a ground truth. After the data gathering, we used machine learning techniques and also classification algorithms to create our model. The goodness of the model was assessed using different metrics and the results showed that it is effective to model both the extraversion and openness personality dimensions using serious games instead of questionnaires.

Keywords: Personality, Game-based learning, Gaming behaviors, Learning analytics, Data analysis

1. Introduction

The utilization of Serious Games (SGs) as an educational tool is a recent phenomenon, and its full potential is yet to be fully comprehended. In recent years there is an increasing focus on adding SGs to the education field. A lot of studies have compared the effectiveness of traditional teaching methods in comparison to an educational SG (Prensky, 2006). Results have demonstrated that educational SGs have a lot of advantages compared to traditional ones. The traditional environment has become boring and unmotivated. Especially a generation born with so much technology around (Barron, 2015).

In comparison educational SGs can be more appealing and encourage the learner to try to apply his knowledge. This gives the possibility for the learner to apply or simulate his knowledge, which can be hard to achieve in a classical environment. In a well-designed educational game environment, the learner can have fun while learning, making the process more enjoyable and less stressful (Schunk, Pintrich and Meece, 2008).

Although learning through gaming may be appealing, not all learners have the same likings. Several studies show that different personalities tend to prefer different learning styles, game genres and playing strategies (Pavalache-Ilie and Cocorada, 2014). The requirements to know each learner's personality have increased in order to better utilize the best-suited teaching model for them. The most used method for modeling the learner's personality is through self-report questionnaires. Using questionnaires has some limitations. The main limitation is that the learner may not answer the questions truthfully. The learner may choose the more socially acceptable answer or hide information if he believes he won't benefit from responding. Another important concern about self-reports is that the learner may not have the necessary self-awareness needed for the questions. Although a lot of these concerns and weaknesses can be reduced by using various techniques, it is clear that using multiple methods to capture the learner's personality is beneficial (Chen and Lin, 2017), (Judd and McClelland, 1998).

This study focuses on creating an educational SG with the ability to model the player's personality type. This can be achieved by capturing the players' game behavior. The design of the SG is focused on capturing the Extraversion and Openness personality traits as they are the most impactful dimensions towards a learning

system. The findings in this study can help the advance of using digital games with a serious intention. More specifically, to have an alternative method of learning a person's personality model as also to better create interactive and engaging methods to assist learners in their studies.

The rest of the paper is structured as follows: Next section presents the background and related work to the current study. In Section 3 the educational game is described and the conducted experiment to evaluate it is presented. Section 4 presents the obtained results from the data analysis. Finally, the conclusions and future directions are given in Section 5.

2. Background and Related Work

2.1 Personality

Personality is the enduring configuration of characteristics and behavior that comprises an individual's unique adjustment to life, including major traits, interests, drives, values, self-concept, abilities, and emotional patterns. Personality is generally viewed as a complex, dynamic integration or totality shaped by many forces, including hereditary and constitutional tendencies; physical maturation; early training; identification with significant individuals and groups; culturally conditioned values and roles; and critical experiences and relationships. Various theories explain the structure and development of personality in different ways, but all agree that personality helps determine behavior (APA, 2023).

In order to predict learners' personalities, various personality models have been proposed in the literature and one of the most used is the Five-Factor Model (FFM) also known as OCEAN (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) model (McCrae and John, 1992), (Franić et al, 2014). This model is one that is both compatible with the present view and consistent with everyday observation. The theory behind this model is that each person can be described by using five traits (Openness, Conscientiousness, Extroversion, Agreeableness, Neuroticism). Each person has a score in each dimension and through the scores someone can determine the tendencies of a person. For example, a person with a high extraversion score may be more outgoing and talkative and in comparison, a person with a low extraversion score may have more introvert habits like preferring to stay at home or being more reserved. To calculate a person's OCEAN score the most common method is through a self-report questionnaire. Each statement in the questionnaire targets one specific trait, the person rates in a Likert scale how much he/she relates with the statement. At the end of the questionnaire after adding the score of each statement the person's personality can be determined. There are some official questionnaires for the FFM. In this research we used the Big Five Inventory (BFI) questionnaire to model our players personalities (John, Donahue and Kentle, 1991) which has been used widely and is found reliable. It contains 44 questions and each question targets one trait of the OCEAN model.

2.2 Related Work

SGs are digital games that have as a primary purpose something different from entertainment. A SG is a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives (Zyda, 2005). For example the SG "Emeraude Escape" was created with the purpose to raise awareness about the importance of data and AI in our daily professional lives. Some other purposes can be art, education, scientific exploration, health care and so on. Of course, as the name implies it is a "game" so although the main purpose isn't entertainment it is still important for the final game to be enjoyable (GAIA, 2023).

Few works have been conducted which used digital games to model the learner's personality. In their study Denden et al. (2017) it was examined what systems and game elements are preferred based on the learners personality. Their study used the OCEAN model for the modeling of the personalities and it was focused only on the extraversion trait (low, balanced, high). The research modeled which game element is preferred or not by the extraversion trait. For example the badges were preferred by low, balanced and high extroversion. This wasn't the case for the leaderboard that was only appealing to the balanced and high extraversion trait.

Denden et al. (2018) proposed a framework for implicitly modeling the learners' personalities within a game-based learning environment using their gaming behaviors. The proposed framework is based on an online role-playing game for teaching the Computer Architecture subject and a learning analytics system. The learners by playing the game generated some game behaviors. In this study by using the BFI questionnaire and the LA system the learners' personality model could be made and evaluated. The efficiency of the proposed framework was evaluated with an experiment of 45 participants which focused on correctly modeling the

Extraversion and Openness traits. The proposed framework had a high level of accuracy with a good and a moderate agreement degree with the BFI.

Afroza et al (2021) developed a 3D digital game for the purpose of measuring some traits of the player's personality. The target of the study was the creation of a method faster and more enjoyable than the traditional questionnaires. The measured traits were based on the OCEAN model and were the Extraversion, Conscientiousness and Neuroticism traits. In their study they validated the proposed game as a personality measurement tool conducting a correlation analysis between the results from the game with those of the BFI. The results showed a moderate correlation on the Neuroticism trait and small correlation on the Extraversion and Conscientiousness.

3. Methodology

3.1 Design of the Game

The game has two main purposes: to assist students in their learning activities and also through their in-game behavior to determine their personality traits. Finally, as a game it should be entertaining. To cover all these targets a story-based game was designed.

3.1.1 Flow of the game

In the game the student plays as a fresh trainee in a small company. The student has to accomplish his "work duties" in the morning. These duties are to review some submitted code snippets from "other" applicants and accept or reject them depending if the snippet is answering a given exercise description. The acceptance or the rejection of the code snippet can be applied by pressing the relevant "accept" or "reject" button. After the learner's evaluation of the code an immediate feedback would occur. The feedback first would inform the player if he/she assessed the code snippet correctly. After the code's assessment an additional text would be provided explaining the answer's main concept. The code snippets are written in the programming language C. After finishing the "work duties" the student can leave the office and go to the "day's event". Every day a different event occurs. At the event the student meets his/her work colleagues and interacts with them. There is a main story that progresses through the days with a final choice at the end of day 8.

The player each day interacts with their work colleagues. Through their conversations the game gathers data about the player's preferences and opinions. The interactions usually are social events like a welcome party, coffee, meetings in the office or going to an art gallery. In the middle of the game there is a special interaction where the company's director goes to the player's office and informs him/her that the company might need to lay off one of their working staff and the player's opinion might be useful. On the last day of the game the director goes to the player's office once more and asks him/her which work colleague the player suggests to lay off and why. The player can give a reason based on the selected colleague's character or declare that the choice was at random.

3.1.2 Design choices

When a player plays a story based game he/she is bound to have a "relationship" with the game's character or avatar (Bowman & Schrier, 2018). There are multiple dynamics and relationships the player can have but this research focused on creating the feeling that the player is playing as himself.

The game elements implemented for this are the first person view, the inability of the player to see his/her body in order to avoid "conflicts" between the avatar's virtual body and the player's real one. Although the game's scenario isn't a common one it is realistic and the conversations between the player and the Non-playable characters (NPCs) are responsive, meaning that the NPCs would say something based on the player's answer making them feel more alive.

Some additional game elements were implemented in order to make the study of the programming language C more appealing and interesting for the player. First there is a score that the player can see on his/her screen. The score is directly influenced by how well the player does his/her "work duties" (Figure 1). If for example the player rejects a correct code snippet his score will decrease. This game element gives a sense of reward in the player's actions and choices. It also emphasizes the impact of the player's choices.



Figure 1: Player's view and score

Additionally, after the player's evaluation of the code snippet there is an immediate feedback. If the player correctly evaluates the code snippet then a green tick will appear indicating that he did a good job. On the contrary if the player made a wrong evaluation then a red "X" would appear. A small text below explains why the principle regarding the correct choice. In this way the player could "fill" his/her learning gaps and quickly realize what he/she knows. The game's feedback is written around the question's concept. For example, in the (Figure 2) the question's concept is that if all the parts of an equation are integers then the result will also be an integer. So " $11/2 = 5$ " and not "5.5" as the "applicant" answered. To avoid having multiple concepts in a single question the code snippets are small in size and don't involve any additional learning concepts other than the targeted one. Furthermore, except for their small size the code snippets contain only logical errors. With this approach the player won't get lost in trying to read a big program or get something wrong just because the code is missing a semicolon (Figure 2). The code snippets the player had to assess address a different learning concept each day. In the first days the code and the questions are focused on more basic concepts of the programming language C and as the game is progressing so is the difficulty of the questions. The code exercises are checking the abilities of the students regarding the flow of actions in C, the use of if-else statements especially how not to mix subsets of conditional statements, loops, the ability of the students to read and understand the code's functionality and finally some general knowledge in C.

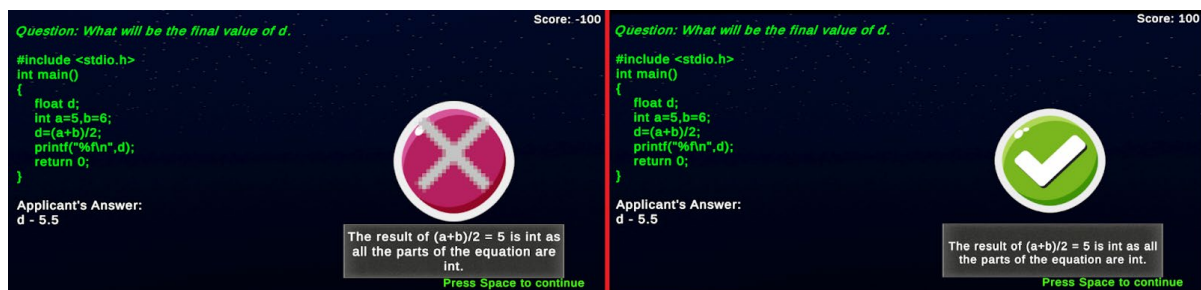


Figure 2: Wrong and correct assessment of the code snippet

For gathering data for the learner's personality an interactive story was created. In the story there were conversations between the NPCs and the learner. The conversations had both questions from the BFI and findings from other researchers regarding the tendencies of the openness and extraversion trait of the OCEAN model (Choungourian 1967), (Watson and Clark 1997).

More specific for the openness trait the conversations were targeting to capture the learner's will to try new experiences, how much risk the learner is willing to take, his/hers views about art, his/hers color preferences and his/hers tendencies regarding the way he/she interacts with the NPCs. For the extraversion trait the conversations were targeted to capture the learner's enthusiasm for communication with the NPCs, his/hers color preference, his/hers will to take risks as also the tendencies regarding answering NPCs. The available responses in the conversations were created with having in mind the targeted trait of the player's answer as also the possible answers a person with each characteristic (low, balanced, high) would give (Figure 3).

The choices from the conversations between the player and the NPCs were used for modeling the learner's personality. Each conversation was saved in an array with categorical values. For example the array [2,1,4] means that the learner selected the second choice in the dialogue then the first and finally the forth one. As

the game was designed to be responsive, interactive and give the feeling of life-like NPCs there were multiple conversation paths. For example, on one occasion the NPC could ask a question, depending on the player's answer a different conversation path could be followed.

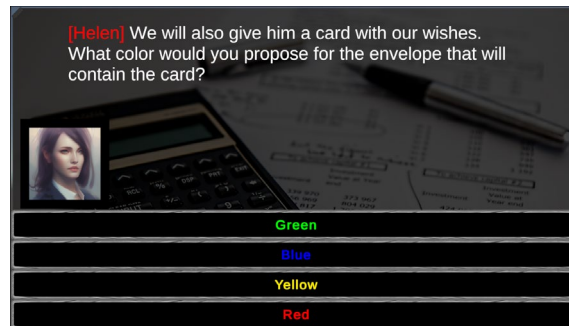


Figure 3: NPC asking player to select color (extroverts tend to prefer warm colors)

3.2 Participants

This research took place in a Computer Science department. The participants were 107 students, 72 male and 35 female students. The students were learning the programming language C (first year curriculum in the university) and they also got a small bonus for participating in the case study. The students first played the game and then they had to fill in the BFI questionnaire in their own time on the same day.

3.3 Procedure

The learners start by playing the game. The game needed around 40 minutes for its compilation. Before the start of the game the learners were introduced to the game's controls and story. At the beginning of the game there was a mini tutorial area to teach the learner's the controls, the user interface and the flow. The learners played the game on their own computer. After the completion of the game the learners had to fill in the BFI questionnaire. A deadline for this task was given not later than the end of the day.

3.4 Data Analysis

For the data analysis the answers to the questionnaire were used as the ground truth. As the game's design was targeting the capture of the Openness and Extraversion trait the given BFI questionnaire had only the questions related for these two traits. More specifically 8 questions were for the extraversion and 10 for the openness trait. As for the trait description there are three distinct categories. Low, balanced and high. To determine each category the mean of the learner's score was used. The mean can be between 1 and 5. The mean-scores in the range 1 to 2.4 were labeled as low, 2.5 to 3.4 as balanced and 3.5 to 5 as high.

First it was checked if there was sufficient data in each category. For the extraversion trait the distribution was 18 learners had low extraversion score, 50 had balanced and 39 had high. For the openness trait the distribution was 2 learners had low extraversion score, 46 had balanced and 59 had high. Because of the low number of learners with low openness scores the prediction of low openness was excluded. After further searching both of the 2 learners with low openness score had a mean score of 2.4 which is the borderline for balanced score. For this reason it was decided to label them as balanced and keep their metrics.

The data gathered from the game were used to predict the results from the questionnaire. As it is already mentioned in the Design choices subsection, the NPC could ask a question and depending on the question the player would answer differently following a different conversation root. Although these conversation paths are small and quickly "reconnected" to the main conversation path they still generate some different arrays. To make the data more homogeneous only the main conversation path was kept. It is important to note here that the choice to drift from the main conversation path was part of the main conversation root.

The player's score as also the success from each player in his/hers in-game "work duties" didn't taken into account for the analysis. We didn't include these two metrics in the analysis as the metrics mostly represent the learner's knowledge for the programming language C and not his personality. To avoid overpopulating the training data with low relevancy data we excluded these metrics.

For the data analysis three algorithms were used: KNN, decision trees and Naive Bayes. The algorithms were trained with various techniques and compared the results. All the models showed better results using firstly PCA to reduce the data dimensions. Also, the models were trained with different training sets (excluding

dialogues or conversations that targeted a different trait of the one we were modeling). Finally, after finding a good model different seeds were tested to find the optimal result. The criteria for choosing a model were through the metrics of f1-score and ROC/AUC score.

4. Results

The results show good scores in both the accuracy metric as also the AUC/ROC score. A different algorithm and seed were best suited for each trait. For the extrovert trait the most suited algorithm was the decision trees. The model can determine extrovert characteristics (low, balanced, high) with accuracy 72% from the game data. Also, the f1-score of 0.736 and AUC/ROC of 0.741 score shows that the model is reliable (Table1). To further determine the agreement degree between the model and the BFI questionnaire the Cohen's kappa coefficient was calculated. Cohen (1960) suggested the kappa result be interpreted as follows: values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement. The decision trees had a score of kappa = 0.54.

For the Openness trait the algorithms had better results. The most suited algorithm was the Naïve Bayes. The model had accuracy of 81% to correctly determine the learner's openness trait (balanced, high). Also, the f1-score of 0.811 and the AUC/ROC score of 0.75 support the model's results (Table 2). Lastly the Cohen kappa score of the algorithm was 0.636 indicating a good agreement with the BFI questionnaire.

Table 1: Extrovert results

Extrovert	Accuracy	F1-score	Kappa	AUC/ROC
Naïve Bayes	0.5454	0.566	0.276	0.627
Decision Trees	0.727	0.736	0.541	0.744
KNN	0.59	0.578	0.292	0.559

Table 2: Openness results

Openness	Accuracy	F1-score	Kappa	AUC/ROC
Naïve Bayes	0.818	0.811	0.636	0.75
Decision Trees	0.545	0.541	0.09	0.998
KNN	0.636	0.633	0.272	0.617

5. Conclusion, Limitations and Future Directions

In this study we developed an educational SG with the purposes of assisting the learner in his studies and additionally from the learner's in-game behavior to model his/hers personality model through the OCEAN theory.

The results obtained by analysing the learners' in game behavior showed a good and a moderate agreement between the study's model of the extraversion and openness trait and the BFI questionnaire. These findings support the hypothesis that the learner's personality can be determined through his/her choices in the game. More specifically the Decision tree algorithm performed better than the other algorithms at determining the Extraversion trait and the Naïve Bayes had better results for determining the openness trait.

In comparison with the related work this study had some differences. The most similar study to this one was the creation of the CAG framework by Denden et al. (2018). In comparison in this study the number of participants was higher and as not a whole framework was created but a targeted game the accuracy of the algorithms were higher. In addition, this study used multiple algorithms to model the learners' personality instead of one.

Although it wasn't inside the scope of this research the results of students' performance during their "work duties" could be used to give some further insight to the professor regarding the students' general level and understanding. For example, if the students show some difficulties on correctly assessing some if-else statements then the professor can further explore if this was due to unclear constructed questions in the game or if the students have some difficulties understanding this concept.

Even though the results are promising there were some limitations on this study. The number of participants of this experiment (107 in total) is not high enough and they were all from the same University. Although there

was a relationship between the learner's choices in the dialogues and his/her personality the dialogues weren't constructed with the help of an expert in psychology meaning not the full potential of the dialogue choices were used.

Some suggestions for future work based on this research: Modeling the remaining personality dimensions through the game data. Use a third personality modeling method in addition to BFI for further comparing the results because as mentioned the self-report questionnaire may be the most used method but it is not perfect. Use adaptive elements in the game based on the learner's personality and study the learner's response to them. For example learner's with high extraversion prefer hot colors over cold. This can be utilized for adding more hot color themes in the game's UI. Finally further research can be done on finding the optimal way for grouping students regarding their personality model.

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