MULTI-LEVEL ADAPTATION OF AN EDUCATIONAL GAME TO INDIVIDUAL STUDENT'S GAMEPLAY, KNOWLEDGE AND EMOTIONS

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Abstract

In recent years, considerable interest has been devoted to the application of games for educational purposes due to their potential to improve learning process and learning outcomes. Such trend can be explained by several reasons, e.g., games increase enjoyment, involvement and motivation, as well as they induce emotions. It is considered that playing games is more emotional than rational process and research shows that emotions are fundamental to learning. They influence perception, attention, decision making, motivation, as well as acquisition and retrieval of knowledge. Learners usually differ regarding their interests, preferences, personality and all these aspects can be considered to provide adaptation. However, differences of individual learners are seldom considered in educational games and emotions as an adaptation source are used even rarely. The main aim of this paper is to introduce a multi-level adaptation approach for personalized educational games to improve their adaptability.

Keywords: Educational games, knowledge assessment, emotions, adaptation.

1 INTRODUCTION

Game-based learning and application of games in educational settings are the subject of increasing attention. Games include goals, rules, content, outcomes and feedback (main elements of any instructional process), as well as they develop problem solving skills, present challenges, competition and encourage social interaction between multiple players (players and learners are used interchangeably). They provide fundamental needs for learning by giving enjoyment, encouraging involvement, increasing motivation, immersion, creativity, social interaction, and emotions [1, 2]. Since engagement and motivation are critical aspects for improving learning gains within learning environments then the encouragement of positive emotions while learners are studying have become as one of the main design goals. Furthermore, emotions are a relevant factor for the assessment of the game itself because emotions will evolve with the events in the game [1].

Games have emerged as a promising research area not only for the learning but also for knowledge assessment because games are all about constant assessment by providing challenges and giving feedback. In many cases, knowledge assessment can lead to negative emotions, e.g., anxiety or fear, if a learner is not confident about his/her knowledge level or if the selected challenge level is not matched appropriately to learner's skills. Analysis of the latest research reveals that despite numerous studies relating emotions with games [3, 4], only in rare cases emotions are actually considered for the adaptation of game elements [5, 6]. Furthermore, an adaptation itself in games is a rare phenomenon. However, it should be noted that learners differ from each other regarding their interests, preferences, learning pace, learning needs, etc. Therefore, an improvement of games' adaptability to consider differences of individual learners with diverse personalities could lead to higher learning results.

In general, adaptation can be ensured at two levels: macro-level (prior to learning, static adaptation) and micro-level (during learning, dynamic adaptation). Such adaptation levels (one of them or both) are implemented more often in intelligent tutoring systems (ITSs), which are created with the aim to provide personalized instruction for individual learners. Similar adaptation approach can be implemented also in educational games; therefore, the aim of this research is a development of a general multi-level adaptation approach applicable for a personalized game adaptation. Besides that, development of a game with integrated emotion recognition is carried out for Artificial Intelligence (AI) course to evaluate an effectiveness of the developed adaptation approach. The main aim is to assess learner's knowledge through adapted game elements leading to increased motivation to learn and achieve higher results not only in the game but also in final exams, in which failure rate has increased notably in the last few years. The most notable reason is that students are not able to attend lectures so the possibility to acquire course topics anytime and anywhere could lead to overall increase of examination results.

2 POTENTIAL OF EDUCATIONAL GAMES AND ADAPTATION

Over the past several years, digital games have entered into the educational area. Games are considered to be beneficial for learning because they incorporate two fundamental aspects: (1) educational aspect related to the learning content and strategies presented to learners, and (2) playful aspect that allows players to act, explore, take rewards, etc. [3]. Games are internally motivating, involve active cognitive, physical, and affective engagement allowing players freely to experiment, fail and recover from failures by trying over and over again [7]. Furthermore, games develop problem solving skills by presenting challenges and providing feedback on performance, offer place for competition and encourage social interaction between players [2]. It is considered that playing games is more emotional process than rational. Emotions are integral part of the learning process since they influence perception, attention, decision making, motivation to learn, as well as acquisition and retrieval of knowledge. However, current game developments for educational purposes rarely consider player's emotions during a gameplay with an aim to utilize them for an appropriate response [5, 6]. The most common approach for the game adaptation is to apply direct mapping of threshold values of measured signals or extracted emotional features to values of game features or elements (e.g., challenge level, solving time, etc.) because this is an easy and straightforward way of achieving adaptivity [8]. By combining positive and negative feedback, challenge and interactivity level it is possible to acquire higher player's satisfaction and keep him/her in the flow state which is considered to be optimal for learning. Ideas about the flow state are based on the flow model developed by Csikszentmihalyi [9]. In the flow model, an occurrence of some emotions like boredom or anxiety shows mismatch between challenge (task difficulty level) and knowledge level, therefore, an arise of such emotions can help to identify, for example, knowledge gaps.

In [8], the author has identified three types of mechanisms to provide dynamic adaptation in games with an emotion-based adaptation: 1) adjustment of explicit, implicit, or player-driven game tasks and their managed appearance in the game flow (game content sequencing, provision and adaptation of automatic help, etc.); 2) adaptation of game difficulty to meet player's anxiety or skill level based on performance; 3) adjustment of audio-visual game elements. These three types of mechanisms can be closely related to a vertical approach proposed in [10] which classifies previously mentioned targets based on three high-level design heuristics for dynamic adjustment of affective gaming – "*assist me-challenge me-emote me*", each corresponding to the specific mechanism type.

Emotions are closely related to motivation and, in general, two potential player's behaviours related to motivation – punishment avoidance and reward acquisition – can be distinguished. Thus, motivation is either to achieve a reward or to try to reduce a punishment depending on goals which a player sets. These two behaviours can be explained by the achievement goal theory [11], in which 2x2 types of goals can be distinguished: mastery goals and performance goals, each in terms of approach (or acquisition) or avoidance: performance-approach (e.g., it is important for me to do better than others), performance-avoidance (e.g., it is important for me to avoid performing poorly compared to others), mastery-approach (e.g., I want to learn as much as possible) and mastery-avoidance (e.g., I do not want to perform worse than previous time). Depending on set goals, emotions, engagement, motivation and gameplay behaviour can be influenced.

Despite all benefits that educational games can provide, their effectiveness in terms of improved learning and learning outcomes is still under question since results of carried out research are often contradictory [12]. However, educational games have a potential to adapt to individual learner by matching together game elements and reward mechanics to learner's actions, performance and learning progress, thus leading to more adapted gameplay. Adaptation is typical capability of ITSs which are created with an aim to provide personalized instruction for an individual learner to improve learning process and learning outcomes. Similar adaptation approach can be implemented also for educational games to ensure game personalization to individual players. Design of multi-level adaptation approach requires obtaining of various parameters related to a learner, game elements, gameplay, etc. One of the most important parameters for the adaptation provision is a personality that is explained in details in the next section.

3 PERSONALITY AND EMOTIONS AS LEARNING KEY FACTORS

Personality and each person's individual differences are part of daily life and they are expressed in feelings, motivation, behaviour, perception, cognition, decision making, etc. [13]. Human personality has been studied for many years by various psychologists, therefore many "personality" definitions exist, e.g. personality "permits a prediction of what a person will do in a given situation" [14] or

personality “represents those characteristics of the person that account for consistent patterns of feeling, thinking, and behaving” [15]. Despite various definitions, a common reason for using personality is the acquisition of unique pattern which helps to predict and explain person’s behaviour (emotional reactions, thoughts, and actions). Regarding emotion recognition, one of the most complex problems is that people may express same emotions differently and personality can help to identify emotion expression patterns [16].

Although regarding personality, there is no consensus among psychologists on the best way how to describe person’s individual differences, many of them recognize the Five Factor Model (FFM). FFM is founded on the principle that people’s differences in their emotional and attitudinal styles can be summarized with five basic traits (also called OCEAN) [17]:

- ***Openness*** – open people demonstrate imagination, innovativeness (like to experience new things), rule breaking. Those who score low tend to be more conservative.
- ***Conscientiousness*** – conscientious people are responsible, reliable, and accurate. They think about all their behaviours’ outputs before acting and take responsibility for their actions.
- ***Extraversion*** – extroverts are outgoing, sociable, friendly and assertive. They are described as active, excited and energetic in achieving their goals.
- ***Agreeableness*** – agreeable people are trustworthy, kind, unselfish, generous, fair, cooperative, striving for common understanding and maintaining social affiliations.
- ***Neuroticism*** – neurotic people tend to experience negative effects such as fear, sadness, embarrassment, anger, anxiety, etc. Those who score low usually are calm and relaxed.

FFM personality traits can be acquired using widely recognized personality inventories, e.g., NEO-PI-R, NEO PI-3, NEO-FFI, etc. For research purposes the most common is NEO-FFI 60-item personality inventory since it takes approximately 10-15 minutes compared to full version (NEO-PI-R) which takes around 35-45 minutes. For the adaptation of instructional process, learners’ personality can be used to identify various parameters influencing their learning. This will be discussed in next sub-sections.

3.1 Personality importance and its influence on learner’s characteristics

Identification of personality can give significant initial information about a learner, including his/her emotional characteristics. It allows predicting learning objectives (for example, achievement of in-depth knowledge or the highest learning results) and the learning style. Furthermore, personality can give clues to the preferred teacher's personality, type and teaching style, which might seem attractive to the learner [18]. Regarding personality matching it is possible to apply so called ‘*law of attraction*’ expressed in human-human interaction [19] and there is evidence that the similarity-attraction hypothesis appears also in human-computer interaction.

By analysing existing studies in psychology, pedagogy and educational psychology related to the influence of a personality on the learning process, it must be concluded that information on the learner’s personality (represented as OCEAN values) can be utilized for the determination of various factors affecting learning/teaching process, e.g.:

- *learner’s default mood* (or temperament) that has an impact on a tendency to specific emotions and their intensity [20, 21];
- *learning style* [22];
- *learning goals*, e.g., in [23] authors have analysed how learning goals which learner tries to achieve within the ITS are related to personality dimensions;
- learner’s intrinsic *motivation* to learn and prone to *academic achievements* [24, 25];
- the most suitable *teacher’s personality, type* and preferences for specific *teaching methods* [18]. Research carried out reveals that learners prefer teachers who are like themselves regarding personality (particularly for openness and conscientiousness) except neurotic learners who prefer agreeable teachers.

Consideration of learner’s personality for the adaptation purposes can be beneficial when implementing interaction mechanisms and making decisions on which teaching actions to carry out next to provide personalized instructional process. Personality can be used an anticipating factor for emotional states of a learner in different learning situations if combined with a learner’s performance and learning goals. Since personality is a stable, long lasting parameter, it can be modelled for static adaptation purposes. Therefore, it can be applied when performing adaptation in the macro-level since this adaptation level utilizes static data [26].

3.2 Personality as an anticipation mechanism

To implement an adaptation of a teaching process the most common approach to ensure initial adaptation (at macro-level) is to assign learner to some group based on static data. Information about personality traits is used as a basis for such learners' classification for this research purposes. Depending on prevailing personality trait a learner is matched to one of the four Kolb's learning styles [27]. Such alignment between personality dimensions and Kolb's learning styles is adopted for this research because various studies are carried out that are trying to find correlations between separate traits and learning styles [28, 29, 30].

Summary of existing research and experiments showing corresponding relationships between personality dimensions and learning styles is represented in Table 1. During the analysis, the main goal was to identify dominant learning style for a particular trait (dark grey colour) and other possible learning styles (light grey colour) for which appeared some correlations but not so clear like in the first case. In few cases, the correlation between these two parameters was not straightforward and other learning styles were also near. This can be explained by the fact that some of personality traits also characterizes an ability to adapt to different situations (various teaching approaches and activities).

Table 1. Personality and Kolb's learning styles

OCEAN / L. styles	**Openness**	**Conscientious-ness**	**Extraversion**	**Agreeableness**	**Neuroticism**
Diverging					
Assimilating					
Converging					
Accommodating					

As it was identified before, a teacher's personality, teaching style and strategy are additional parameters that can be determined based on a learner's personality. Since it is possible to acquire corresponding learning style from a personality then this information helps to identify appropriate type of a teacher that implements customized teaching process in a manner consistent with a learning style. When there is a match between the instructional approaches used by a teacher and the learner's preferred learning style then teacher-learner interaction and relations are enhanced, leading to improved psychological, affective, academic and behavioural engagement [31].

Regarding this question, the analysis is conducted to differentiate for each of learning styles the most appropriate teacher type and instructional strategy that will be selected when initiating the learning process (macro-level adaptation) [32, 33]. Results of the analysis are summarized in Table 2.

Table 2. Kolb's learning styles and corresponding teacher and teaching styles

	Diverging	**Assimilating**	**Converging**	**Accommodating**
Teacher's type	Motivator, friend (personal model)	Expert	Coach, delegator	Evaluator/remediator, facilitator
Interaction with teacher	Teacher ↔ Learner Both active but initiative comes from a teacher	Teacher→Learner Teacher active, learner passive	Learner→Teacher Learner active, teacher guides to right direction	Learner ↔ Teacher Both active but initiative comes from a learner
Teaching strategy and methods	Direct instruction (modelling-scaffolding approach) Demonstrations and practice; learning by watching, analysing	Direct instruction (didactic approach) Lectures or presentations; learning by listening, watching	Indirect or interactive instruction (managerial approach) Interactive, hands-on or computer-assisted instruction	Indirect, interactive instruction (dialogic approach) Socratic dialogue and questions; learning by discovery, learning by doing

Besides all previously mentioned parameters, it is possible to distinguish four player types [34, 35] as well as to see similarities both with Kolb's learning styles and achievement goals:

- ***Socialization-oriented player*** – this player type is interested in people and communication. In the game, such players try to get to know people and establish friendship. This player type can be considered as an idealist, so certain similarities exist with learners aiming at mastery (focus on avoidance). This player type can also be tied to diverging learning style since someone's guidance is important and it goes along with modelling-scaffolding approach.
- ***Winning-oriented player*** – this player type strives for competition and contest. Such players like to win others by using different means and they feel good if someone else suffers from their actions. Since the main goal is victory then this type is similar to learners whose achievement goal is performance (orientation on avoidance) because loss is considered as the worst possible outcome. This type can be matched to accommodating learning style since challenges, competition and practical activities, as well as emotions are important.
- ***Achievement-oriented player*** – this player type mainly is interested in activities available in a game environment. They like collecting points and enrich their profile and/or character. They try to get all available achievements of a game, therefore, interest in interaction or competition with others is expressed only to reach these aims. Since the main goal of this player type is objectives and achievements then there can be found similarities with learners whose aim is performance (orientation on approach). This player type can be matched to the convergent learning style because activities and achievements are characterizing such learners' interests.
- ***Exploration-oriented player*** – this player type focuses on discovering the game world and game mechanics till everything is clear (big picture is seen), even hidden secrets and possibilities. These players can be compared with learners whose achievement goal is mastery (focus on approach) since knowledge and wisdom are the most important ones. Therefore, some similarities exist with assimilating learning style because clarity, structure and understanding of the whole are essential for these learners.

All previously analyzed information is utilized for the development of multi-level adaptation approach. Most of considered aspects serve as an adaptation source for the macro-level since this level is related mainly to static data. Design of both levels (macro and micro) is described in the next section.

4 MULTI-LEVEL ADAPTATION OF THE TEACHING PROCESS

Educational games like other learning environments have a potential to adapt to characteristics of an individual player by matching together game elements to player's actions, performance and emotions. For this purpose, general ideas from ITSs are adopted to ensure game adaptation. In general, instructional adaptation can be provided at two levels: 1) at macro-level that is realized prior to learning based on static player's data available to system (or game) before learning (gameplay) and 2) at micro-level that is ensured during the learning/teaching process based on dynamic player's data acquired in a real-time during the gameplay, e.g., based on responses, actions, emotions, etc.

4.1 Design of multi-level adaptation approach

In this sub-section, design of multi-level adaptation approach is described. Both levels (macro and micro) are created based on the analysis carried out and summarized in previous sections.

4.1.1 Macro-level adaptation

To ensure macro-adaptation, before the game starts, the learner's prior knowledge and gaming skills, (e.g., beginner, expert) and preferred learning style are considered by combining these parameters with the learner's personality represented as Big Five personality traits. Personality traits give information not only about the learner's personality but also about default mood or tendency to some specific emotions, preferred learning style, teaching approach, and motivation towards goal achievements, as well as personality traits allow identifying player's type matched to listed parameters.

Overall, the macro-level adaptation process is represented in Fig. 1. To ensure adaptation at the macro-level, personality inventory is offered to the learner if he/she enters the system (game-based environment) for the first time. Acquired personality traits are stored in the database (student model) together with accompanying parameters – identified learning style, teacher's type, teaching strategy, achievement goals and default mood. Default mood is calculated based on formulas provided by Mehrabian [21] to convert OCEAN values into Pleasure, Arousal, and Dominance (PAD) space.

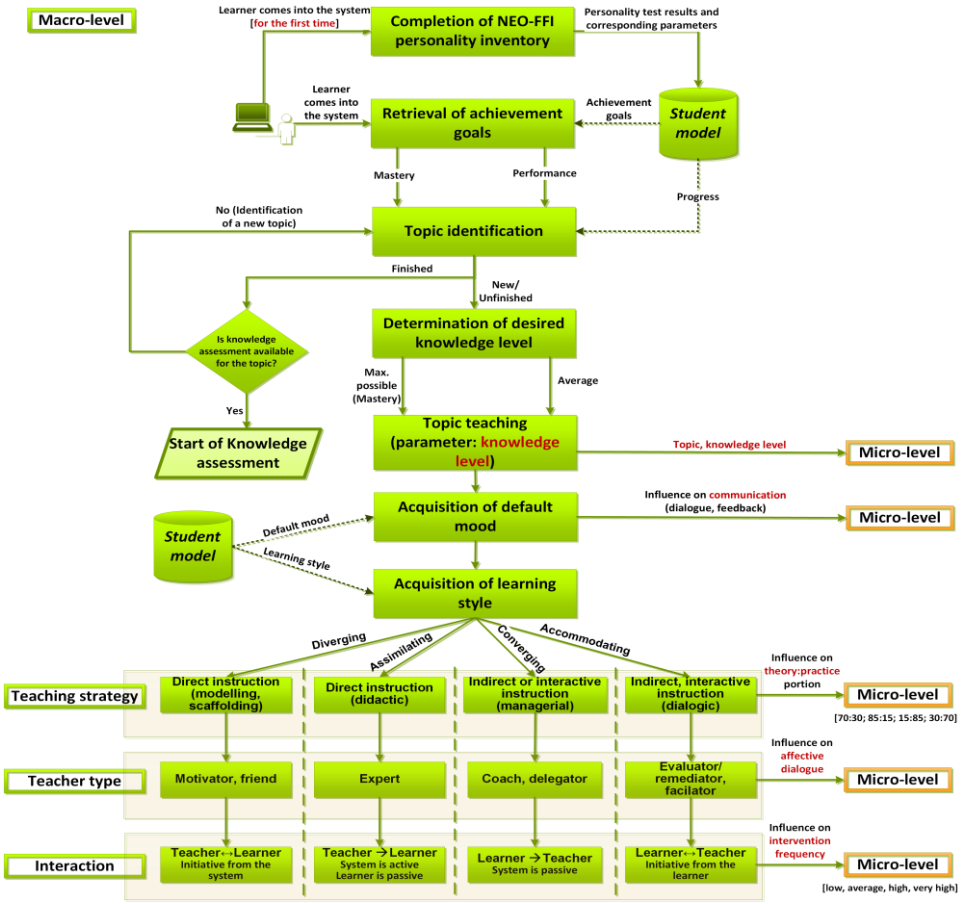

Figure 1. Macro-level adaptation.

This information allows acquiring the personality influence on emotional states. After storing all parameters, topic is identified based on progress and achievement goals, as well as learner's desired knowledge level is defined. If topic is acquired and there is available knowledge assessment for it then learner has a possibility to start it. Otherwise, teaching process is initiated to reach defined knowledge level – either maximum level for mastery oriented learners or average level for performance oriented since they aim on faster movement through learning process. In addition, such parameters as learning style and corresponding teaching strategy, teacher type and interaction are obtained. After macro-level adaptation, the system initiates micro-level adaptation which is specified in the next sub-section.

4.1.2 Micro-level adaptation

As gameplay starts, micro-adaptation based on dynamic parameters is initiated. Emotions are also considered as one of the parameters, since they are occurring and changing during the gameplay depending on the perception of game elements, challenge level, the learner's knowledge, and playing skills, achievements and provided feedback. Emotions serve as an information source for identifying being in the flow state when task difficulty is matched to player's knowledge level and skills.

When **teaching** process is initiated, first of all, the amount of theory is considered. If minimal theory is required then brief introduction is given, otherwise, theory is provided together with demonstrations (demo level). Demonstrations can be shown by the system itself or with the learner's involvement. If learner is also engaged in activities, then (affective) feedback on actions is provided depending on the teacher's type and action results. Emotion monitoring is ensured during whole teaching process and if negative emotions are detected then based on their analysis and teaching situation observation, teaching is either repeated (e.g., if confusion is detected), modified (e.g., boredom) or carried on (e.g., if teaching situation is frustrating but it is required for continuing learning). Positive emotions are promoted by giving positive or motivational feedback.

Depending on results of teaching step, **practice** comes as a next in appearance of various challenges. If theory was minimal, then more emphasis is put on practical training, during which some theoretical information can be provided as tips or advices. Furthermore, depending on a task and difficulty level additional options (as a help) are available. Learner can use these options to solve task but it is

important to remember that this will affect the result (score and achievements). During the practice, learner's actions and performance are analysed (time required to solve, asked help, correctness of solution, etc.) and based on the teacher's type and interaction level various interventions are carried out by the system. In addition, emotional reactions are evaluated to identify situations or system's actions that caused negative experiences and facilitated positive ones. Negative emotions can be a sign of missing knowledge, help required or too low challenge. Therefore, various reasons can serve as emotion triggers and timely system's response is required to reduce their negative effect on the learning (e.g., motivation decrease, appearance of misconceptions, etc.).

After finishing practical training (when desired knowledge level is reached), learner can start **knowledge assessment**. This integral part of the instructional process is also implemented with an emotion monitoring. Only in this case, interventions are not realised during the knowledge assessment itself but afterwards. Such difference is ensured because knowledge typically is evaluated during exams or tests when learners should use only their own knowledge without others' help. Besides that, interventions (kind of disturbances) could only promote emergence of negative emotions (e.g., anxiety or frustration). If learner should do something in limited time, then this will create an extra tension during knowledge assessment. After finishing assessment, results are analysed and feedback is given both on incorrect answers and on questions in which negative emotions were detected.

4.2 Implementation of game-based environment

Currently, the development of a 2D game is carried out as part of affective tutoring system created for teaching topics in the course "Fundamentals of Artificial Intelligence" (see Fig. 2) involving also emotion recognition based on facial expressions for the adaptation of the game. The main aim is to assess learners' knowledge through adapted game elements leading to increased motivation to learn and achieve higher results not only in the game but also in final exams, in which failure rate has increased notably in the last few years. Emotions are considered as one of parameters since they are occurring and changing depending on the gameplay. In Fig. 2, game menu and developed levels for one of the AI course topics (search algorithms) are shown, as well as some of results of the gameplay are displayed. Main task is to show algorithms' iterations by using drag-and drop to place iteration elements in correct lists (OPEN or CLOSED). Depending on a difficulty level various additional options are or are not available and different game elements are added, e.g., wrong items for iterations or time set for level accomplishment. Furthermore, pedagogical agent (teacher) is embedded into the game to carry out teaching activities, provide assistance or feedback on actions.

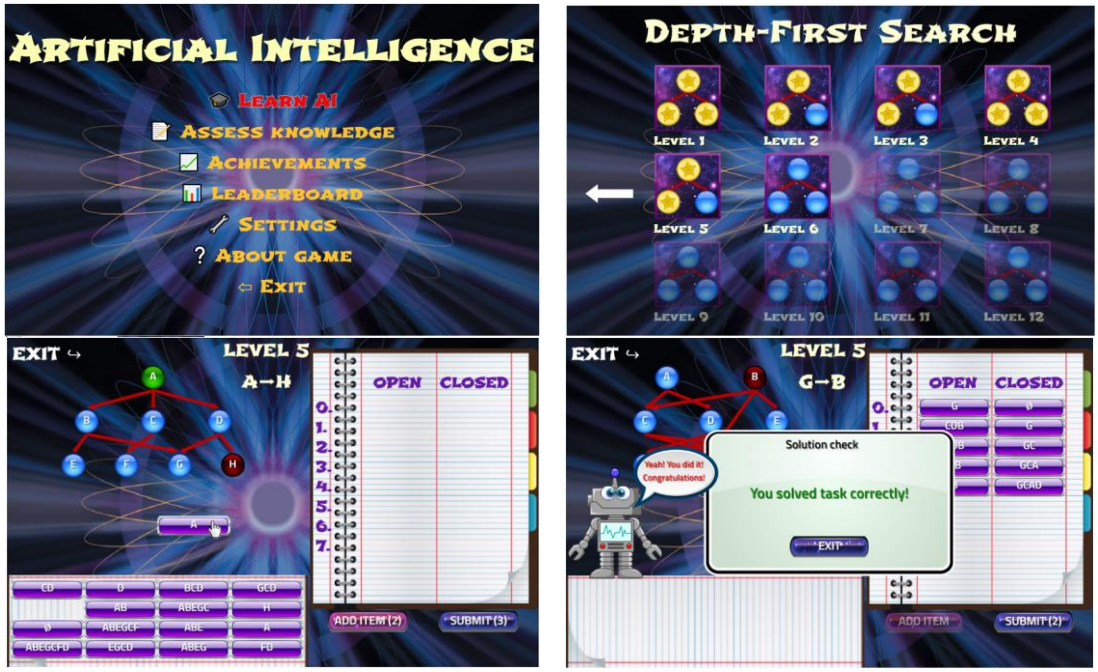

Figure 2. Game interface and gameplay activities

Currently, game is still in the development stage, however, some of main parts for the adaptation provision is implemented, for example, personality identification and determination of corresponding parameters, as well as emotion detection and identification using camera data.

Personality assessment is implemented by adopting widely recognized NEO-FFI 60-item personality inventory (for foreign students) and modified version NEO-FFI-L 40 item inventory (for Latvian students) to acquire Big Five personality traits. NEO-FFI-L personality inventory is based on NEO-FFI only it is adapted to Latvian society [36]. Based on personality test results default mood, learning style and corresponding teacher and teaching style is assigned (see Fig. 3).

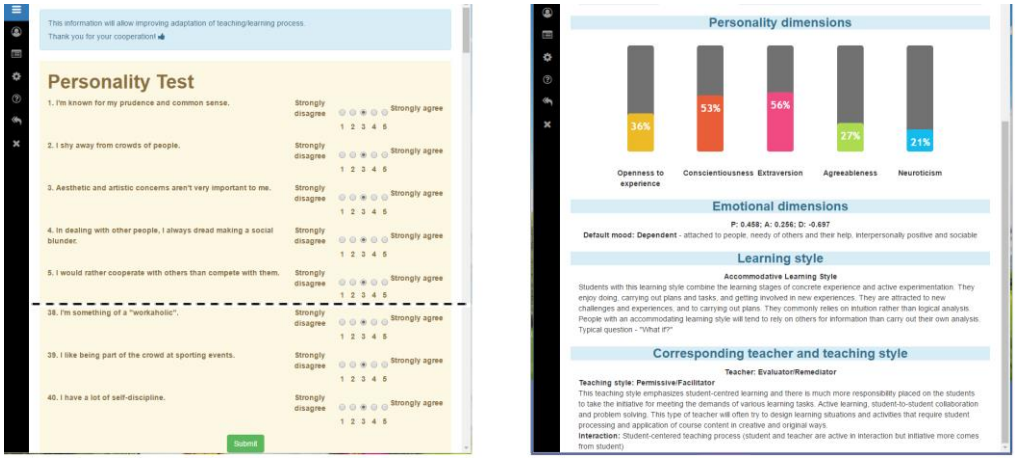

Figure 3. Personality test (for Latvian students) and acquired information about a student.

Automatic emotion identification is implemented based on the analysis of facial expressions, particularly, by analyzing facial actions [37] and their combinations to recognize such emotions as joy, sadness, surprise, flow, confusion, boredom, anxiety, and frustration. These emotions are considered as the most common in the learning process [38]. Since game is created as web-based solution then Emotion API developed by Affectiva is adopted for the research purposes (see Fig. 4).

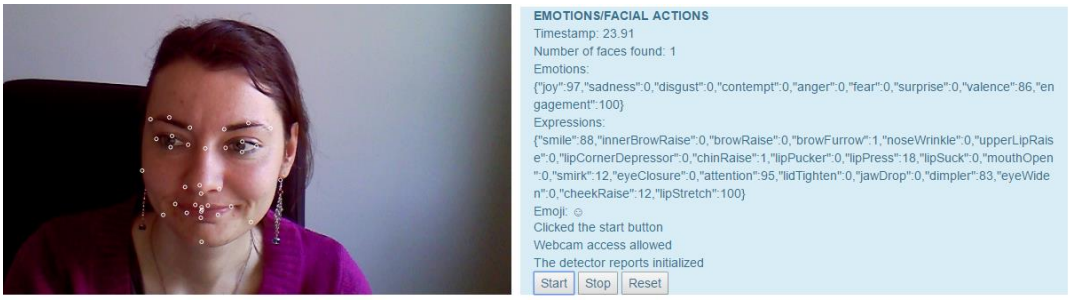

Figure 4. Adopted Emotion API and its output results

This tool allows tracking movement of facial actions, engagement, attention, and recognizes basic emotions. To recognize other emotions studies regarding emotion identification were analyzed to identify characteristic facial actions for these emotions.

5 CONCLUSIONS AND FUTURE WORK

Although educational games can provide various advantages, their effectiveness in terms of improved learning and learning outcomes is still questionable and acquired results are contradictory. It can be explained, first, by the fact that during the design process of educational games such aspects as instructional design and pedagogical principles are often not considered and incorporated as part of games. However, designers cannot forget about the main goal of such games – facilitation of the learning process. Therefore, attention should be paid to learning content and not so much on entertaining game-based features. The second reason is the lack of various teaching methods which would account for individual learner's differences. Thus, some learners will be left behind just because their learning needs are not met by the game design. Addressing these two identified issues could improve game adaptivity. Multi-level adaptation approach is introduced in this paper to improve adaptivity problems and provide personalized instruction through game environment. In addition, development of a 2D game environment is initiated to evaluate an effectiveness of proposed approach in terms of increased comprehension of AI course topics which will be the next step of this research. Therefore, future work is related with the improvement of game's adaptability during the gameplay (at the micro-level) and evaluating its influence on learning and exam results.

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