Improving Play and Learning Style Adaptation in a Programming Education Game

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Abstract: The drive to teach programming to K-12 students has amplified in the past few years as several European countries have added programming to their national curricula. Teaching programming is not simple as even older students struggle with the topic. Educational games have been shown to increase motivation and learning efficiency, and many games have been created to teach programming. Adaptation is a technique that could improve these benefits even further by personalizing the game to learners in a heterogeneous group. In this study we presented Minerva, an adaptive programming education game designed for elementary school students. The game uses Bartle's Player Types and Honey and Mumford's Learning Style Questionnaire to adapt gameplay and learning content to match the player's styles. We tested Minerva with 33 6th grade South Korean students using a post-test questionnaire, interviews, and a game log that was designed to keep track of the students' profiles and how Minerva adapted to them. Based on the results, we proposed how Minerva's adaptation system can be improved in the future. This paper can be of interest to anyone researching possible uses of adaptivity in (programming) education games.

1 INTRODUCTION

Programmers are in great demand. A European Union report stated that Europe will have up to 756 000 ICT job vacancies by 2020 (Hüsing et al., 2015). South Korea is among the latest countries that have decided to add programming education to their national curricula (Ministry of Education and Science, 2015). Several European countries have already upgraded their K-12 curricula (Balanskat and Engelhardt, 2015), and non-profit organizations, such as Code.org, are pushing for similar reforms in the U.S.

Various tools, such as Scratch, are used to teach programming to children. However, the need to teach the core programming concepts still remains, and with programming being a challenging topic to teach to even older students (Gomes and Mendes, 2007; Jenkins, 2002), this is an issue not to be taken lightly. Educational games can yield positive results and are one possible solution (Connolly et al., 2012). Majority of programming education games tend to be one-tracked puzzle games, which some players may find difficult to approach if the game style does not suit them (Charles et al., 2005; Magerko, 2008). Using adaptation could alleviate these issues and improve motivation and learning (Hwang et al., 2012).

We developed a programming education game, Minerva, that adapts learning content and gameplay to the learning and play styles of the player, respectively. In this paper, we describe Minerva's adaptation model and show the results of its evaluation with 6th grade students in South Korea. Finally, we give suggestions to improve adaptation in games such as Minerva.

2 BACKGROUND

2.1 Learning and Play Styles

We have previously compared several learning style models (Lindberg and Laine, 2016) and selected Honey and Mumford's LSQ and Bartle's Player Types for the basis of adaptation in Minerva because of their simple terminology and wide use in related fields.

Honey and Mumford identify four learning styles as follows: (i) Activist, who learns from experience and prefers acting over thinking; (ii) Reflector, who learns by observing others; (iii) Theorist, who learns by analyzing and prefer to theorizing over doing; and (iv) Pragmatist, who learn by applying theory in prac-

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tice. Though the learner may utilize all four styles, they naturally prefer one over the others, which becomes the primary learning style.

Bartle's Player types was created as a taxonomy of MUD (Multi-User Dungeon) players. Since then, also single player gamers have been labeled directly with Bartle's Player Types or with other models that are based on Bartle's. In his model, Bartle divided players into four styles: (i) Killer, who prefers acting upon other players using dominance and aggression; (ii) Socializer, who prefers communication over gameplay; (iii) Explorer, who prefers discovery (e.g. hidden locations and bugs) driven by curiosity; and (iv) Achiever, who prefers winning by points, achievements, and collectibles in a competitive manner.

2.2 Adaptive Learning Environments

Adaptivity in learning environments is the process of transforming the learning environment (e.g., learning materials and activities, user interface) to match the learner's context, which can comprise different dimensions, such as personal context (e.g. learning style, knowledge level, emotional state) (Akbari and Taghiyareh, 2014), technical context (e.g. device type), and spatio-temporal context (Hsu et al., 2016).

Recent surveys analyzed the integration of learning styles into learning environments (Akbulut and Suzan Cardak, 2012; Truong, 2015). Diverse learning style models have been utilized in the adaptation processes (Akbari and Taghiyareh, 2014; Yaghmaie and Bahreininejad, 2011; Latham et al., 2012), and Ruiz et al. (Ruiz et al., 2008) proposed two ways in which learning styles can be used in adaptation: a) adapting learning material type, and b) adapting learning content structure. Some recent learning environments do adaptation in ways that hardly fit to the aforementioned classification. For example, Akbari et al. (Akbari and Taghiyareh, 2014) proposed a recommender system that finds a helper (another learner) by comparing and matching learning styles of the help seeker and the helper candidate. In other studies, the sequence of learning content has been adapted based on learning styles (Yaghmaie and Bahreininejad, 2011; Cabada et al., 2011; Latham et al., 2012). Vesin et al., in their Java tutoring environment, implemented adaptation of presentation method and navigation according to the learning style (Vesin et al., 2012). For example, if the learner with visual learning style cannot earn required grade for a specific concept, the learning environment changes his learning style to verbal. Moreover, navigation is adapted according to sequential and global learning styles.

Learning environments detect learning styles by versatile methods. Most systems rely on questionnaires (Akbari and Taghiyareh, 2014; Vesin et al., 2012; Cabada et al., 2011), but others methods, such as discourse analysis (Latham et al., 2012), also exist.

2.3 Adaptive Educational Games

Adaptation is used in games to make them more intriguing for a heterogeneous group of players. Chen discussed the need for adaptive game design and how games can maintain the flow for different players (Chen, 2007). Chen suggested giving control to players through choices that affect the flow of the game, but warns against giving too much freedom that could be overwhelming or annoying. To overcome this conundrum, Chen proposed: "offer adaptive choices, allowing different users to enjoy the flow in their own way; and embed choices inside the core activities to ensure the flow is never interrupted".

Educational games have a heterogeneous audience with likely occurrence of different gaming preferences. Using adaptation has been perceived as a possible method for alleviating this issue. For example, Magerko's take on adaptation in educational games is to use knowledge with pedagogical and entertainment values: "Games for learning can incorporate modeling approaches for both pedagogical and entertainment goals. A game can be tailored to both better engage as well as educate the player by using both kinds of knowledge." (Magerko, 2008) Moreover, Magerko listed common adaptation techniques for games: a) Branch story into multiple paths; b) Track the player type and change the game according to the player's preferences; and c) Use Non-Player Characters (NPC) that adapt their behavior to different player types.

Several adaptive educational games have been proposed. Kickmeier et al. (Kickmeier-Rust et al., 2011) introduced an adaptive storytelling framework in which the story is adapted according to the player's the needs and interests. Similarly, Peirce et al. (Peirce et al., 2008) utilized adaptation in their physics education game to give motivational and hinting support to the player. Hwang et al. (Hwang et al., 2012) used the Felder-Silverman learning style model to adapt the appearance of their game.

3 MINERVA

3.1 The Game Concept

Minerva is a programming education game for elementary school students with no previous programming experience. The player is given a clear goal and purpose through a simple story in which the player is remotely commanding a robot sent to a derelict spaceship, Minerva, to repair it back to working order. The game covers five core programming concepts: input, output, math, repetition and decisions. Minerva does not have separate puzzles for Math, Input and Output, but they are inherently part of the gameplay (i.e. giving input commands to the robot and observing its actions as the output) and covered in the game story.

Minerva has several features that set it apart from other programming education games. Firstly, many programming games are simple puzzles without a storyline. Secondly, puzzle games' levels are generally not connected to each other except by the increase in difficulty. In Minerva, the player is free to traverse the ship. Thirdly, the player can use a chat communicate with other players in the same room. Fourthly, some rooms can be solved in several different ways: the player can shoot obstacles and aliens blocking the way; talk to the aliens and convince them to leave the room; or simply maneuver the robot past the obstacles. Fifthly, Minerva has minigames for teaching programming concepts. These repair missions, which thematically connect to the story, are short puzzles that focus on a single programming concept. The game has two such puzzles on repetition and decisions. Lastly, Minerva adapts content and gameplay to the player's learning style and the play style.

3.2 Adaptation

In this section, we explain how a questionnaire for mapping the play and learning styles was created and how the adaptation is done within Minerva.

3.2.1 Questionnaire

A questionnaire was created previously to identify children's learning and play styles (Lindberg and Laine, 2016). In Minerva, the questionnaire is part of player account creation and it has two parts. The first part covers play styles based on Bartle's Player Types, and the second half is for learning styles according to Honey and Mumford's Learning Style Questionnaire. Each style has four Likert scale statements, resulting in 32 statements. If the player scores evenly for multiple styles, an additional statement for each equally rated style is shown, of which the player must choose one to be the primary style.

3.2.2 Adaptation to Play Styles

Play style adaptation affects the number of aliens and the active view shown to the player. For example, Killers are provided with the maximum number of aliens, whereas Sozializers will see the minimum number of them. There are three different auxiliary views in Minerva: score, chat and map. The active view depends on the detected play style: Achievers see the score view, map is for Explorers and chat for Socializers. There is no active view for Killers when the game starts. The player can change the active view at any time. View contents are identical to all players, with the exception of the map view: for Explorers the map only shows the areas that the player has visited. This technique is known as the fog of war.

Minerva adjusts play styles by tracking players' behavior. For instance, if a Socializer behaves like a Killer, or an Achiever shows tendencies towards Socializer, the style is updated accordingly. The parameters used for tracking play behavior are aliens and destructible obstacles. Aliens are used to track Killers' and Socializers' behavior. Firstly, the player can have a dialog with aliens, which is appealing to Socializers. The dialog offers hostile options, which could appeal to Killers. Players who decide to talk to aliens and convince them to leave the room peacefully, will get their Socializer score increased, whereas a player who destroys aliens will have their Killer score strengthened. This way the game adapt itself to play styles beyond the questionnaire results. Explorer is an exception to this as an Explorer's behavior is not tracked.

3.2.3 Adaptation to Learning Styles

Minerva's learning style adaptation is based on Magoulas et al.'s adaptive navigation in a web-based learning system (Magoulas et al., 2003), which uses three adaptation levels: (i) Remember, which is associated with recalling the theory; (ii) Use, which relates to applying the learned theory; and (iii) Find, which is the ability to propose and solve original problems. In Remember, learning content is divided into three parts: 1) Question, 2) Example, and 3) Theory. Learning content is shown in different order per learning style. Fourth part, Activity, belongs to the Use level.

We simplified and combined Remember and Use levels to make Magoulas et al.'s framework fit the game environment and target group. The Find level was omitted because the game is does not require higher level pedagogical skills. Learning content in Minerva is divided into four parts with different media modalities and simple terms: (i) WHY: text that includes learning content explaining how the current topic may be used outside the learning activity (e.g., a puzzle). This is equivalent to Theory; (ii) WHAT: images that show the learning activity to the player and what the player is expected to do. This is equivalent to Question; (iii) HOW: a video clip that shows the player how a similar learning activity is solved, equivalent to Example; and (iv) DO: This is the actual learning activity, equivalent to Activity.

Table 1 presents Minerva's adaptive learning content ordering model. This ordering adheres to Magoulas et al.'s level Remember, with the exception of Activist for which we placed DO after WHAT. This was done to ensure that the puzzles' goals are clear to the player before solving them. Unlike play styles, learning styles are not updated during gameplay.

Table 1: Adaptive ordering of learning content.

Activist	WHAT	DO	HOW	WHY
Reflector	WHY	HOW	WHAT	DO
Theorist	WHAT	WHY	HOW	DO
Pragmatist	HOW	WHY	WHAT	DO

4 EVALUATION

4.1 Research Design

Minerva was evaluated at a South Korean elementary school with 32 grade 6 students (F: 15, M: 17). A teacher and 12 students were also interviewed. Here we focus on evaluating Minerva's adaptation model.

In addition to utilizing the play and learning style questionnaire, we created a post-test questionnaire with Likert scale statements and open answer questions. The post-test questionnaire was filled right after gameplay. Semi-structured interviews for students and their teacher were also prepared.

Minerva collects essential game data such as: play and learning style profiles, room entering and exit times, obstacles destroyed, aliens removed by talking or destroying, puzzle entering and exit times, total moves performed, and game start/end times. Additionally, all chat messages are stored to a database.

4.2 Results

The results in this section are based on Minerva's log system with some results from the questionnaire and interviews when they relate to adaptation.

4.2.1 Play Styles

Minerva has a simple internal point system that is meant for adaptation handling. Shooting aliens, talking to them, and destroying obstacles give points for Killers, Socializers and Achievers, respectively. As we mentioned before, Minerva currently does not track adaptation towards Explorer.

Table 2: Initial and final play styles scoring by Minerva.

		Achiever	Killer	Explorer	Socializer
Start	μ	4.64	3.15	3.03	4.97
	σ	3.34	3.64	3.31	3.75
	$\sum$	153	104	100	164
End	μ	4.70	4.85	3.03	6.42
	σ	3.36	4.57	3.31	3.14
	$\sum$	155	160	100	212

Figure 1 shows play styles at the start and end of the game. In the beginning, Socializer was the most common primary play style and Achiever was the second most popular. Secondary play style results were more even, with only minor leaning toward Achiever. The least favorite style was Killer. It should be noted that questionnaire results could all be given negative results, in which case the least negative is marked as the primary play style. Additionally, some players do not have tertiary or quaternary play styles; instead, they could have several equally strong play styles grouped as the secondary style. For example, a female player's results were as follows: Achiever: 4p, Killer: -2p, Explorer: 0p, Socializer -8p. This makes her primary play style Achiever, however, despite been given 0p to it, the player's secondary group was Explorer.

In total, eight players' styles changed during gameplay. The changes were either to Socializer (three) or to Killer (two), and three players' primary play styles were identified as combinations: Killer-Socializer, Killer-Achiever and Achiever-Socializer.

Style changes are quantified in Table 2 with mean (μ), standard deviation (σ) and sum($\sum$) of points per style. The largest increase in points was for Killer, with a total of 56p being added to players' profiles by the end of the game. Killers were followed closely by Socializers with 48p. These are fairly substantial point hikes compared to Achievers' 2p.

Tendencies towards Socializer were observed during the gameplay, with players talking together and helping each other to solve rooms and puzzles. Furthermore, several players chatted actively through the provided chat system, though majority of the conversation were mainly emoticons and jokes. Some played did ask for help over the chat system, but they did not receive any help through the chat. Additionally, one player identified as Socializer made a request of just chatting, instead of playing the game:

> **Male player (Chat)**: "Hey guys, let's chat rather than beat this game"

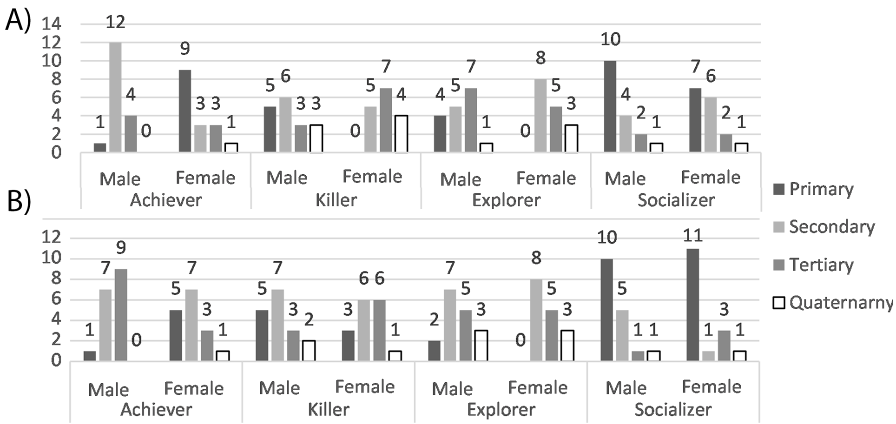

Figure 1: Play styles of the players: A) at the start of the game B) at the end of the game.

A majority of chatting occurred in the first and final rooms. There were also several messages left in other rooms, but these were largely from a male player who spammed seemingly random letters and occasional emoticons. At the start of the game, this player was identified as an Explorer, with only one point difference to Socializer and Achiever as secondary styles. Generally, female players did not use the chat as much as males for chatting; either they left one or two comments, or simply asked for an advice. Out of 15 females who played the game, only five wrote something on the chat, whereas 14 out of 17 male players partook the chat. Female players also wrote fewer messages, though this is slightly skewed due the substantial spamming done by a handful male players, some of whom found it amusing:

> **Male player (Chat)**: "Spamming this text is so fun"

One female player, who had asked for help in the chat, suggested an improvement to the game:

> **Female player (Questionnaire)**: "It would be nice if this game provided an easier tutorial"

At the beginning of the game, she was identified as an Achiever with one point difference to Killer and Socializer. By the end of the game, Socializer had been set as her primary style and secondary style was a combination of Killer and Achiever. These styles are also supported by the player's comment:

> **Female player (Questionnaire)**: "I had fun when I talked with aliens and killed aliens"

Though only commented by a few students, the chat system garnered only positive feedback:

> **Female player (Interview)**: "The chatting system is so fresh, like an online game"
> **Male player (Questionnaire)**: "I liked the chat"

Interacting with aliens was also positively received by players, even if they only would talk to one of the aliens and then proceed to destroy others. For instance, the following comment was left by a player who talked to an alien, destroyed the others, and had been identified as a Killer from the start:

> **Female player (Questionnaire)**: "I like this game when I talked with aliens, because their appearance was so funny"

4.2.2 Learning Styles

Primary learning styles are identified from questionnaire results and cannot change during gameplay. Figure 2 shows that Activist was the most popular learning style with 14 designees. The results have been calculated in a manner similar to play styles, meaning that actual points do vary more, as we see in Table 3. Activist and Reflector are closer to each other with a difference of 19 points, which is substantial compared to Theorist and Pragmatist.

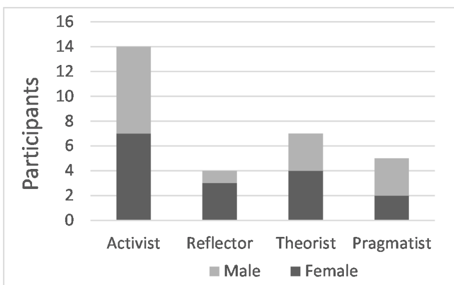

Figure 2: Learning styles.

We observed that many players ignored tutorials completely and just clicked to get to the game as quickly as possible. This behavior supports the results above suggesting that a majority of players leaned towards the Activist style. Some negative feedback was

Table 3: Learning styles scoring.

	Activist	Reflector	Theorist	Pragmatist
μ	2.82	2.42	1.45	1.82
σ	3.73	3.64	3.03	3.54
$\sum$	93	80	48	60

towards the tutorials and learning content, for instance one female player complained about lack of instructions for controlling the robot:

> **Female player (Questionnaire)**: "It was difficult to understand the game tutorial [...] It would be better if the tutorial has more explanation about robot control, obstacles etc"

This was despite Minerva showing a set of images and a video describing how the robot controls work. Other students complained about instructions in general, and lack of information about learning objectives was pointed out by the teacher:

> **Female player (Questionnaire)**: "The instructions were hard to understand"
> **Male player (Questionnaire)**: "It would be nice if the instructions explained in more detail and precisely"
> **Female teacher (Interview)**: "The game was excellent but to use it in a real programming class it can be improved a bit. [...] the learning objective was not so clear. Core contents and learning objective should be apparent."

5 DISCUSSION

In the following sections, we discuss how Minerva could be updated based on our evaluation results to handle the play and learning style adaptation even better. These ideas are applicable to other adaptive games based on the same models.

5.1 Improving Play Style Adaptation

The initial play styles mirrored the players' behavior in most cases, as only eight players' play styles were changed during gameplay. Additionally, a large number of players had a close number of points in more than one style. This was also indicated by comments from the questionnaire where a few players stated both enjoying talking and shooting aliens.

Minerva does not consider the relevance of secondary styles. For instance, if Achiever and Explorer are both valued much higher than Killer and Socializer, it would be safe to assume that the player has tendencies for both styles. Consequently, the game should adapt its behavior to support both styles.

Minerva's adaptation system is currently rather simple, and it is unsure whether it suffices in a longer test scenario. Some of the originally planned adaptation functionalities were not fully realized simply due to lack of time. For instance, Achievers are only mildly supported, with only one room filled with barrels that they could destroy to collect points. Some simple modifications in future iterations will be directed towards the Achiever class, such as random destructible obstacles and dropping collectibles that will give extra points to the player. Essentially, these drops can happen with any play style, but if the player keeps destroying barrels, the chance of gaining collectibles would increase. Additionally, for more competitive Achievers it would be appealing if each room and puzzle would display the highest score that any player has cleared it with, and scoreboard would display the total high scores. Lastly, by adding collectible achievements, for instance clearing a room in a specific way, would be motivating for Achievers.

When adapting a game for Explorers, extra game content, such as hidden or visible objects and rooms, must be generated. Another possible way to support Explorers is to leave harmless bugs in the game that a player can use to their benefit. Killers and Socializers are the easiest styles to handle, which could explain why they were prominent player types at the end of the game. In a future version, both will be supported with diverse dialog paths for Socializer and stronger feedback in form of audio and graphics for Killers when they destroy aliens and obstacles.

Table 4 summarizes our play style adaptation improvement ideas. Additionally, the game world could also change according to secondary styles. For example, Socializers would normally have the minimum number of NPCs and the default number of destructible obstacles. A Socializer with Achiever as secondary style would have the usual number of NPCs, with a higher number of destructible obstacles and elevated chance for collectibles. A Socializer having Killer and Achiever as secondary styles would, in turn, have the maximum number of NPCs.

5.2 Improving Learning Style Adaptation

Although players complained about difficult puzzles and tutorial contents, it does not mean that the current method of providing educational materials is fully at fault. The players were understandably excited for having a gap from their usual activities. We observed their hurry to get to the game as several players skipped most tutorials in the start of the game. Further testing is required to see how well the learning content

Table 4: Play style adaptation improvements. Default value is between minimum and maximum numbers a room can handle.

Play Style	User Interface	Game World	Destructible Obstacles	NPCs
Neutral	Unaltered	Unaltered	Default number; Default chance for collectibles	Default number
Killer	Unaltered	Unaltered	Default number; Increased audio-visual effects; Default chance for collectibles	Maximum number; Increased audio-visual effects
Achiever	High-score shown; Achievements collected; Achievements available	Room high-score shown;	Maximum number; Increased chance for collectibles	Default number
Explorer	Deliberate bugs that give advantages	Hidden rooms and objects; Extra rooms	Default number; Default chance for collectibles	Default number
Socializer	Can initiate chat with any online player	Unaltered	Minimum number; Default chance for collectibles	Minimum number; More complex dialog options

and the game are received in long-term. Nonetheless, it is clear that there is room for improvement.

Because Minerva is an educational game, learning content provision must be done with care. Learning content should be spread so that it will not distract gameplay. To achieve this, the usage of learning styles is important, as well as the correct design of puzzles, especially when the topics start to become more complex. A puzzle itself should be presented without additional text convey the topic at hand. In repetition and decision puzzles, this was achieved with relative ease, but with more complex topics maintaining the same level of clarity can be challenging.

An unobtrusive method of learning material delivery is voice-over. This would particularly support players who prefer listening over reading. Moreover, Minerva already uses images in tutorial content, but these were based on screenshots of the game. More carefully crafted and visually pleasing tutorial images could yield increased attentiveness from the players.

Minerva changes the content presentation order depending on learning style. This can be improved by considering more the needs of each style. Activists could directly start the puzzle without any tutorials shown, with an option to open the tutorial later. For Reflectors, a larger change is recommended: recording other players solving a similar puzzle and allowing Reflectors to view a recording. For Theorists and Pragmatists, the focus should be on how to make learning materials more appealing. This could be done for example by splitting materials into practical and theoretical parts, or highlighting relevant parts. For Activists and Reflectors, both materials could be made available and Minerva could also track which type of material the player prefers to see.

Table 5 lists the aforementioned improvement ideas. Learning content is marked as: theoretical, practical or the combination of the two. Theoretical includes the theoretical aspects of the topic, and practical explains the theoretical aspects briefly followed by real-life examples. This type of division works better with more complex topics; simpler concepts can be presented with the same content for all styles.

Table 5: Learning style adaptation improvements.

Learning Style	User Interface	Learning Content
Neutral	View tutorials in any order	Theoretical and Practical content highlighted
Activist	On-demand tutorials	Theoretical and Practical content highlighted
Reflector	View a recording of another player solving the same puzzle	Full content
Theorist	Show tutorial before puzzle	Theoretical content highlighted
Pragmatist	Show tutorial before puzzle	Practical content highlighted

5.3 Limitations

This study has several limitations that should be considered in future research: (i) the evaluation did not measure the influence of adaptation to learning and motivation; (ii) Minerva does not adjust all styles dynamically (i.e. Explorer, all learning styles), which may cause imbalance and mismatch; (iii) currently unknown influence of game design to learning/play styles could help make design decisions that support adaptation; and (iv) existing criticism against learning and play styles should be accounted for.

6 CONCLUSIONS

In this paper we introduced Minerva, an adaptive programming education game that uses Bartle's Player Types and Honey and Mumford's LSQ to adapt both gameplay and learning content. We also showed the results of adaptation evaluation obtained from testing Minerva at a South Korean elementary school, and proposed improvements for the adaptation model based on evaluation results. There is room for improvement especially on how the learning content is shown to players and on the adaptation of play and learning styles.

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