OMEGA: A Multiplayer Online Game for Improving User's Meta-Cognitive Skills

Abstract — **Meta-cognitive skills, like problem solving skills, are extremely important for people. According to recent research done by The Conference Board of Canada, problem solving in technology-rich environments nowadays is positively associated with the probability of participating in the labour market and being employed. Research also shows that a student can be a more confident and independent learner when he or she has better meta-cognitive skills. This research aims to design and develop an educational game that aims at improving four meta-cognitive skills while people are playing. Those skills are: (1) problem solving, (2) associative reasoning, (3) planning and organization and (4) accuracy and evaluation. The research team has proper evaluation plan designed and research ethics approval obtained for recruiting participants to use OMEGA. This paper also explains the details of the evaluation plan and the instruments of data collection in the end.**

Keywords- meta-cognitive skill; mini game; competition; educational game; browser-based game; problem solving; associative reasoning; accuracy and evaluation; organization and planning

I. INTRODUCTION

Meta-cognitive skills represent a person's ability of understanding, controlling, and manipulating his or her cognitive processes and can be taught so his or her learning can be improved [31]. When a student has better meta-cognitive skills, he or she can be more confident and independent learner [1]. Meta-cognitive strategies are different from cognitive strategies while latter are mentally and/or physically manipulating the material to be learned with previously acquired concepts or skills, the former are about the process of planning, monitoring production, evaluating how well a goal/objective is achieved [16].

Meta-cognitive skills are very important in today's economy. While Canada is doing well in producing people with university, college and trade credentials, the actual skill levels in key areas like critical thinking, problem-solving, innovation, etc. are underwhelming [27]. Those skill deficits limit people's potentials and their contributions to their employers, thus, having a negative impact on Canada's economy overall.

Assessment is important for education to evaluate and understand students' understandings of knowledge and skills of solving problem tasks. To assess students' knowledge and skills of particular learning topic, teachers usually ask them to take an exam in which a lot of items are included. Take Ricketts and colleagues' research for example, the researchers asks students to take eight tests with total 1000 items to evaluate students' knowledge [29]. Students might feel bored and refuse to take the tests, especially when the tests are not direct affecting their academic scores.

Although one-to-one tutoring is proposed and confirmed that it can increase students' achievement by two standard deviations [2], nothing more important than engaging students to the learning or training process to solving the problem tasks. If students don't be motivated in terms of using a method/tool for learning, they won't use it and learn no matter how good the method/tool is.

Educational games can make learning more engaging because they are interactive. There are six utilizations of gaming include teaching, experimentation, entertainment, therapy and diagnosis, operations, and training [34]. Numerous educational game research that use gaming for teaching have been done to help students learn language [8], mathematics and physics concepts [4, 6, 22], programming languages [5, 17], and management information systems [25]. Also, research in the design of games serving different audiences were studied. These include, assisting the elderly to improve skills around selective attention to tasks [7], addressing on-the-job training for adult participants [24], familiarizing financial literacy concepts for youth [15], nurturing the habits of self-regulated learning in adolescents and practice of the knowledge they learned [3], and the training of autistic children in their daily activities skills [18]. Experiments using these games have demonstrated positive and encouraging outcomes in regard to student achievement [8, 15].

But simply developing and adopting an educational game in a learning environment and process is not guaranteed to students' learning motivation can be increased [41]. Even the novelty of an educational game can increase motivation at very beginning, but that interest will fade over time as the students get used to the game play [40]. It is extremely important for an educational game to include some motivational techniques that can encourage the students continuous playing.

Moreover, some brain training games have been developed by companies like Lumosity, Fitbrains and Cogmed, for training players' memory, attention, speed, etc. [12]. Cognitive psychologists and neuroscientists believed

that there is no scientific evidence to prove those games can make users smarter [26].

This paper introduces OMEGA (see Figure 1), Online Metacognitive Educational Game with Analytics [32, 33], an educational game that includes ten competition-based subgames and each of them can be used to train and assess one of the four meta-cognitive skills players have. The four meta-cognitive skills namely problem solving, associative reasoning, accuracy and evaluation, and organization and planning.

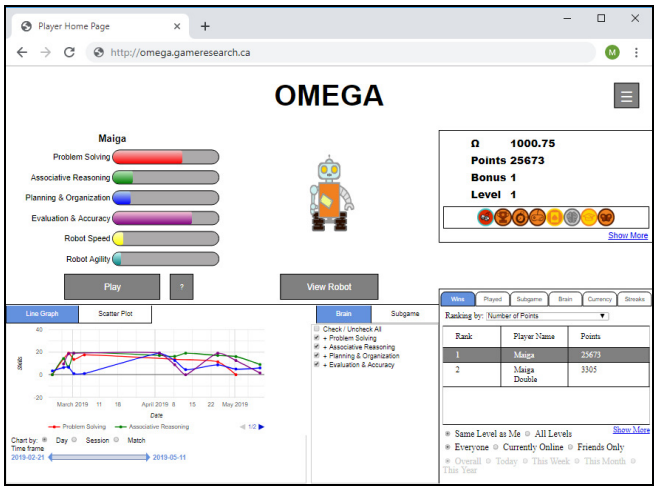


Figure 1. The main screen of OMEGA[1].

In OMEGA players play matches consisting of a set of three subgames against each other. For each subgame played, a performance score is calculated that shows how well the player played that subgame. A metacognitive skill score in a mini game is calculated based on the performance score as a percentage value compared to the highest possible performance a player can get. The player's overall score for a particular metacognitive skill comes from the highest scores in all subgames associated with the same metacognitive skill.

From Section II to Section V, the ten subgames would be introduced. At the end, Section VI talks and explains the evaluation plan the research team has designed and is ready to do. Section VII concludes the paper with a brief summary and next steps.

II. Problem Solving Subgames

Two subgames, Bypass and Viroid!, are designed and developed for focusing on Problem-Solving meta-cognitive skill training and assessment. The end goal of the two subgames is to potentially improve an individual's problem-solving meta-cognitive skill by solving the problems created in each level.

Bypass is a problem-solving game that focuses on two types of problems [14], troubleshooting and rule-based, as the game has both rules that govern the problem (bypassing the broken infrastructure) and allow for flow control and fault states (how game pieces interact with the world). In addition to this, Bypass attempts to solve ill-structure problems, which according to [30] are problems that have more than one outcome or are problems that can result from another problem.

Bypass (see Figure 2) is a competitive puzzle based problem-solving game that challenges players to identify alternative ways to bypass clogged underground pipes that are considered broken. Players can either replacing existing functional pipes or deploy new pipes with the goal of bypasses the broken infrastructure.

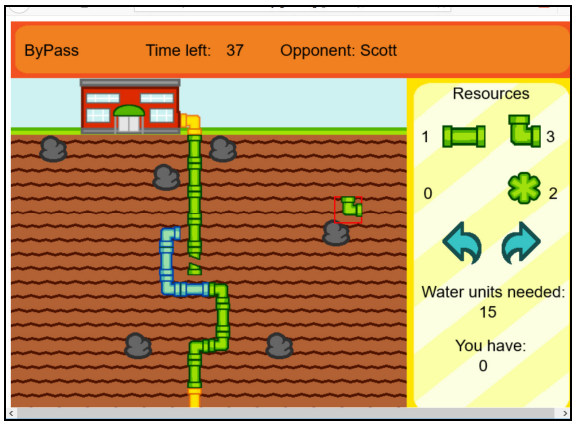


Figure 2. Subgame Bypass for Problem Solving.

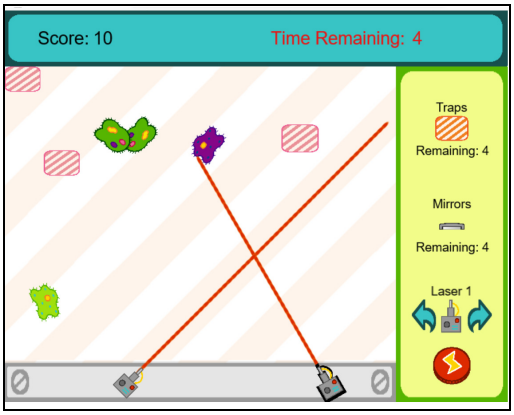


Figure 3. Subgame Viroid! for Problem Solving.

Viroid! focuses on two types of problems [14], logical and rule-based, as the game has a set of logical rules that govern how each player resources (lasers, mirrors and traps) interacts with non-player controlled resources (infect cells, healthy cells, cell-blocks and walls). Similar to Bypass, Viroid! attempts to solve ill-structure problems

Viroid! (see Figure 3) is an action based problem-solving game that encourages players to identify different approaches to restore infected cells by capturing and inoculate them using a series of reflect mirrors, and lasers and movement traps.

[1] url removed for blinded reviewing

III. ASSOCIATIVE REASONING SUBGAMES

Three subgames, Crossplay, Pattern Hacker, and Pirate Hunter, are designed and developed for focusing on Associative Reasoning meta-cognitive skill training and assessment.

Crossplay (see Figure 4) challenges players to identify and play word cards that they feel best associates to the main word that they are presented with. Players must complete as many words as possible until either the timer ends, or when they have reached the maximum number of words for that level. Players are dealt a series of different cards (target domain) that potentially are associated to the main theme and puzzle word (source domain) that are initially presented.

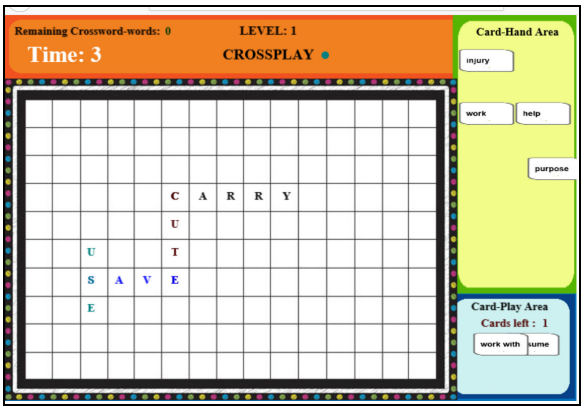


Figure 4. Subgame Crossplay for Associative Reasoning.

Words that are being used are well-defined objects that exist in the external world [28] and by using similar words (synonyms) or directly related words (dictionary words), players are clustering information based off similarities to help create inferences [35]. This method of card distribution supports the ideas that one stimulus can be mapped to another in the same world [21].

The design of Pattern Hacker is inspired by the mental rotation test [39]. The difference is the players are not verifying objects are same or not but finding the relations between an object and its very last and next ones to tell the forthcoming pattern that is unrevealed yet.

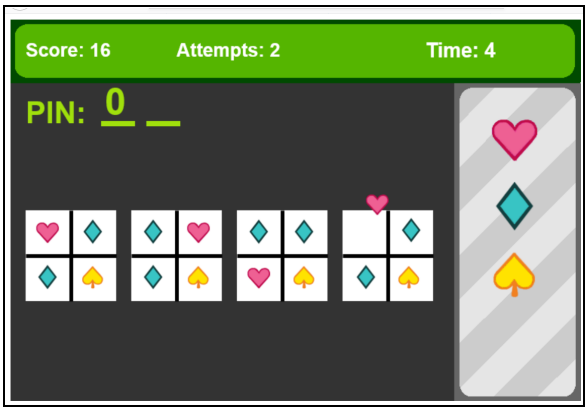


Figure 5. Subgame Pattern Hacker for Associative Reasoning.

In Pattern Hacker (see Figure 5), the player pretends that they are a Hacker that needs to break into someone's account. The account is password protected and the PIN changes on a regular basis. However, the player is given information about the previous three PINs. If the player can identify the pattern that generates the PIN, the player can correctly identify the account password. The algorithms that generates the PIN digits is displayed as four symbols in a PIN pattern grid. The positions of the symbols in the grid change between each PIN digit. If the player can identify the next pattern for each of the PIN digits, then they can unlock the account.

Pirate Hunter (see Figure 6) is a competitive multiplayer image-association puzzle game that includes two stages. The first stage asks players determine which picture, out of several, a distorted image was taken from the original picture and the second stage challenges players to locate the original positioning of the distorted image in the original picture. Pirate Hunter manipulates a key part of the main puzzle image by either using blurring, colorization or pixilation techniques. This allows a key component of the image to be obfuscated, which potentially hides the context of the image. Players need to identify images that they feel best associate to the situation in the image, and what they feel has been obscured.

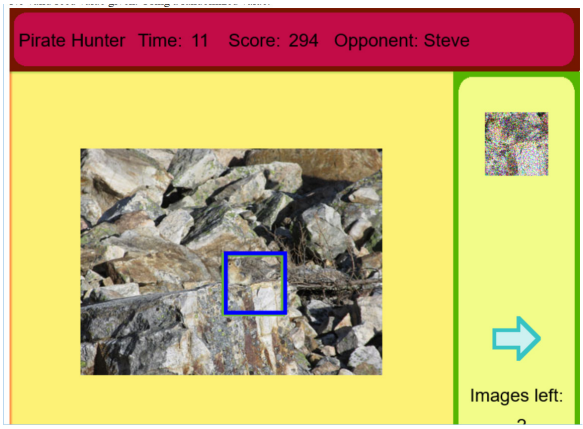


Figure 6. Subgame Pirate Hunter for Associative Reasoning.

By using different obfuscation methods on the main puzzle image, players need to search for relevant information [23] and must rely on previous experiences or cues [19] from the image. By doing so, players should be able to identify the best solution to the game and allow them to potentially create new relationships or strengthen those that already exist.

IV. ACCURACY AND EVALUATION SUBGAMES

Two subgames, Card Swap and Delivery Dash, are designed and developed for focusing on Accuracy and Evaluation meta-cognitive skill training and assessment.

Card Swap (see Figure 7) is a subgame based on the card game three-cards-monte. The game starts with a bunch of playing cards face side up. Some of the cards are chosen as target cards, which means that the players will have to track the location of those cards as the card locations are swapped.

The players are scored on how well they found the objects and how confident they are in their answers. The game objective is to correctly and confidently identify the position of all the target cards.



Figure 7. Subgame Card Swap for Accuracy and Evaluation.

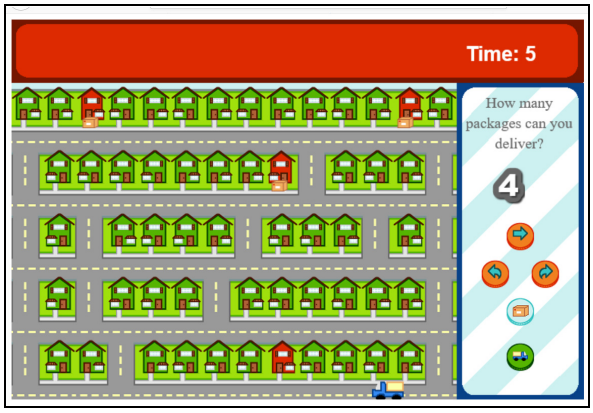


Figure 8. Subgame Delivery Dash for Accuracy and Evaluation.

Delivery Dash (see Figure 8) is a subgame where the players have to program a self-driving truck to make multiple deliveries. The players will be able to see the map and where the deliveries are while they decide. They are then asked how many deliveries they think they will make before they program their delivery truck, which will serve to measure the confidence of the player. Once they decide, they can program their truck by pressing the buttons: rotate left, forward, rotate right, and deliver. The players will not be able to see the previous commands that they have given the truck as they program it, so the game will require both attention and some working memory. The players are scored by how many deliveries they made, and if they were correct in their guess. The game objective is to correctly and confidently program the truck to make all of the deliveries.

V. Organization and Planning Subgames

Three subgames, CR2k, Evacres, and Weekend Barista, are designed and developed for focusing on Organization and Planning meta-cognitive skill training and assessment.

CR2k (see Figure 9) encourages players to organize a cycling trip by performing route and equipment planning and organization. Players are exposed to different events that potentially hinder or benefit them during their trip. Players can use equipment to counter and benefit from those events, however players need to reach the end of the route before running out of energy or risk losing the game.

While CR2k tries to simulate some of the elements of a cycling trip, the game is primary a non-technical simulation that supports the concept of improving route planning skills (organization and planning) through game simulation [20] by creating levels with multiple routes with different sets of observable positive or negative events (meta-cognitive learning strategy [9]).

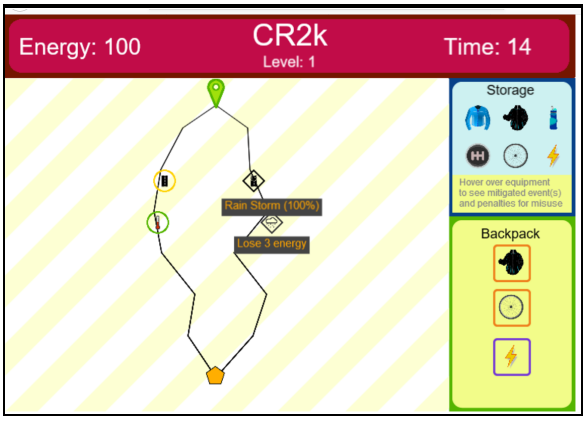


Figure 9. Subgame CR2k for Organizaing and Planning.

Evacres (see Figure 10) encourages players to organize and plan how to maximize the value of their land tiles by attempting to exploit positive events and negating negative events. Players are given random land tiles (resources), where they are presented with random events that can have positive, negative or unknown impact. Players play action cards to attempt to benefit or mitigate the random events. Players who have the highest score by the end of the game are considered the winners.

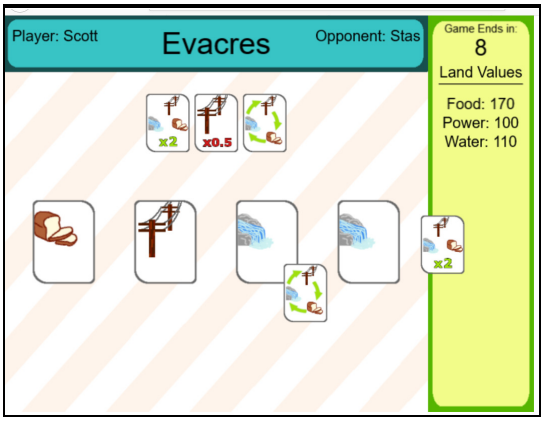


Figure 10. Subgame Evacres for Organizaing and Planning.

Beside benefiting from cognitive and meta-cognitive strategies via planning of land and actions while observing events, Evacres also allows player to select which action cards they wish to play, which means players are able to have self-control over their actions and set their own goals, which is part of being an active learner [10] and have control over how they address aspects of strategic planning, such as dealing with threats and opportunities [13].

Weekend Barista (see Figure 10) encourages players to organize and plan resources and priorities (regular and special coffee orders) of a coffee shop that are needed to complete the weekend orders. Players have different types of resources they need to manage while trying to predict to an extent the amount of daily orders compared to regular orders that they might receive based on various factors, including the weather. Each level consists of two rounds representing Saturday and Sunday. Players have the choice to modify their resources at the start of each day.

Similar to both CR2k and Evacres, players need to use meta-cognitive learning strategies to observe upcoming event conditions and plan out what course of action they wish to take in order to benefit the most from them. Similar to CR2k, Weekend Barista players need to manage their resources (cup sizes, sugar, cream and ice) while trying to predict the usage of those resources throughout the weekend.

While Weekend Barista is simulating a coffee shop environment, it is not simulating the technical side of brewing coffee, but more of the non-technical skills that may be needed to manage a coffee shop, such as resource management [38], resources priorities and planning [37], and taking advantages of opportunities and reducing threats [13], such planning for weather events.



Figure 11. Subgame Weekend Barista for Organizaing and Planning.

VI. Evaluation Plan

The research team plans to broadly announce OMEGA through many different channels (e.g., within conferences, within universities, through social media platforms, etc.). The primary target audience of the game OMEGA are adults (e.g., university students, people in the workforce, etc.). There are two types of data that will be collected within the evaluation: (1) data from different questionnaires; (2) log information from OMEGA (secondary use of data).

In the evaluation plan approved[2] by Research Ethics Board, OMEGA will be evaluated with respect to four issues. Each issue will be evaluated through a separate evaluation with different participants.

1) Those four issues are:

a) Effectiveness of subgames to improve meta-cognitive skills

This research will include the evaluation of each subgame with respect to whether or not playing the subgame increases the respective meta-cognitive skill. Furthermore, this research will investigate how accurately OMEGA is identifying meta-cognitive skills of players. In addition, this research will include investigations into the relationship between the players' meta-cognitive skills and how they use, behave and perform in the game.

b) Usability of OMEGA

This research will include the evaluation of the usability of OMEGA as well as investigations into the relationships between perceived usability, perceived enjoyment of the game, purpose for playing, how players use, behave and perform in OMEGA and demographic and gaming-related factors (i.e., gender, age, educational level, academic/job-related background, gamer type, preferred game genres, hours per week for playing computer games).

c) OMEGA Players' attitude towards computer games

This research will include investigations of the relationships between players' general attitude towards computer games, demographic and gaming-related factors (i.e., gender, age, educational level, academic/job-related background, gamer type, preferred game genres, hours per week for playing computer games) and how players use, behave and perform in OMEGA.

d) Player's behavior, usage and performance in OMEGA

This research will include investigations into data on how players use, behave and perform in OMEGA.

In the following paragraph, the research questions (RQs) of the five evaluations studies planned to be conducted within this project are described.

2) Research Questions (RQs) of the five evaluations:

a) Evaluation 1

- RQ1: How effective is each of the ten subgames in improving the associated meta-cognitive skill? [each subgame is associated with one meta-cognitive skill which it aims to improve]
- RQ2: How do the players' meta-cognitive skills identified in OMEGA relate to their meta-cognitive skills as identified through the questionnaires?
- RQ3: What is the relation between the players' meta-cognitive skills and how they use, behave and perform in the game?

b) Evaluation 2

[2] Ethics File No.: 23541

- RQ4: What is the perceived usability of OMEGA?
- RQ5: Are there relationships between the perceived usability, perceived enjoyment of the game, purpose for playing, how players use, behave and perform in OMEGA and demographic and gaming-related factors (i.e., gender, age, educational level, academic/job-related background, gamer type, preferred game genres, hours per week for playing computer games)?

c) Evaluation 3

- RQ6: Are there relationships between players' attitude towards computer games, demographic and gaming-related factors (i.e., gender, age, educational level, academic/job-related background, gamer type, preferred game genres, hours per week for playing computer games) and how players use, behave and perform in OMEGA?

d) Evaluation 4

- RQ7: How are players using, behaving and performing in OMEGA?
- RQ8: How do players use, behave and perform in OMEGA differently, comparing the desktop and mobile version of OMEGA?

RQ1 investigates how effective OMEGA is in increasing players' metacognitive skills and RQ2 investigates whether meta-cognitive skills are correctly identified in OMEGA. RQ4 aims at investigating the perceived usability of OMEGA. The other research questions aim at investigating how players use OMEGA and who the typical players of OMEGA are (e.g., players' in a particular age group, with a particular gender, with a particular educational level, etc.). By knowing who the typical players are, we also know for whom OMEGA is not that attractive yet and can work towards improving OMEGA to reach a wider audience.

The research team has also designed and planned the following methods and procedures for each of the four evaluations. The detailed information, related instruments, and data analysis approaches can be seen below.

3) Methods and Procedures

a) Evaluation 1

For each of the ten subgames, 50 participants are sought who would go through the following steps:

- Step 1: Depending on the meta-cognitive skill that is targeted by the subgame (e.g., problem solving), a respective questionnaire (e.g., problem solving questionnaire) will be presented to be filled out.
- Step 2: Players are expected to play OMEGA and complete 50 matches.
- Step 3: After the 50th match, the same questionnaire as in step 1 would be presented to be filled out.

Participants will be invited to the evaluation right after they created an account in OMEGA. To answer RQ1 and RQ2, the results from the first and second questionnaire will be compared and brought in relation to the respective meta-cognitive skills identified by OMEGA. Statistical tests (e.g., t-test, u-test, correlation analysis) would be used for this analysis. To answer RQ3, statistical analysis will be conducted on the data about meta-cognitive skills and the log information.

b) Evaluation 2

In this evaluation, 50 participants will be asked to participate. Invitations to participate will only be sent out after a potential participant has completed 15 matches in OMEGA. In order to participate, participants only have to fill out the Usability Questionnaire. To answer RQ4, the results of the questionnaire will be summed up and average ratings will be built to get an understanding about the general perceived usability of OMEGA as well as its features and subgames. To answer RQ5, statistical analysis (e.g., t-tests, u-tests, correlation analysis, etc.) will be used to investigate relationships between the perceived usability, perceived enjoyment of the game, purpose for playing, how players use, behave and perform in OMEGA and demographic and gaming-related factors (i.e., gender, age, educational level, academic/job-related background, gamer type, preferred game genres, hours per week for playing computer games).

c) Evaluation 3

In this evaluation, 50 participants will be asked to participate. Invitations to participate will only be sent out after a potential participant has completed 2 matches in OMEGA. In order to participate, they only have to fill out the Attitude Questionnaire. To answer RQ6, statistical analysis (e.g., t-tests, u-tests, correlation analysis, etc.) will be used to investigate the relationships between players' attitude towards computer games, demographic and gaming-related factors (i.e., gender, age, educational level, academic/job-related background, gamer type, preferred game genres, hours per week for playing computer games) and how players use, behave and perform in OMEGA.

d) Evaluation 4

No active participation from players is required for this evaluation since this evaluation will be based on log information that has been already stored in OMEGA (secondary use of data). To answer RQ7, statistical analysis (e.g., descriptive) will be used. To answer RQ8, statistical analysis as well as data mining algorithms will be used to find differences in how players use, behave and perform in the desktop and mobile versions of OMEGA.

VII. CONCLUSION

There are many different emerging technologies that can enhance learning. One of them are educational games. Educational games have the potential to make learning more engaging because, unlike traditional media, games are interactive. Educational games present players with challenging problems to solve, which is what makes a game fun [11]. Learning is implicit from the feedback they receive about the actions they have taken, or choices they have made in the game [36].

Developing an educational game is not easy. One of the main research challenges in educational games is how to combine gaming aspects and learning aspects to create a game that is fun to play but also facilitates learning while learners play, preferable in a way that learners do not even notice that they are learning while they play. In this research, the research team aims at designing and developing the educational game OMEGA that fulfills this important objective, namely to help players increase their meta-cognitive skills while playing. Such improved skills will boost users' learning capacities, whether at university or on the job; will make further education easier; enable them to deliver high quality work; empower them to realize their full potential; and overall, make a stronger contribution to our economy. To the best of our knowledge, no educational game exists that focuses on increasing players' meta-cognitive skills such as the ones OMEGA is focusing on. As such, OMEGA is a novel educational game that has high potential to improve people's lives.

The research team has designed and developed the game OMEGA that includes 10 subgames and each of them is designed carefully for a specific meta-cognitive skill according to the different elements identified in the literature review. Moreover, a detailed and complete evaluation plan is ready and approved by research ethics board. The evaluations aim at finding out whether OMEGA is effective in improving players' meta-cognitive skills, how easy it is to use the game (perceived usability) and which types of players are attracted by the game (and which types of people are not attracted).

The results of the evaluations will be used to improve OMEGA in terms of making it more effective in improving players' meta-cognitive skills, making it easier to use and making it attractive for a broader range of people. Participants of this research will benefit from such improvements. In addition, by improving OMEGA, more people can benefit from it in terms of being able to increase their meta-cognitive skills through playing. Given that OMEGA is the first educational game that targets to improve players' meta-cognitive skills, our findings will be a valuable contribution to the research community in game-based learning.

So far, OMEGA has been developed for desktop computers/laptops. Soon we will also start implementing a mobile version of OMEGA. This research will then also consider and include the evaluation of the usability of OMEGA's mobile version as well as investigations into the relationships between perceived usability, perceived enjoyment of the game, purpose for playing, how players use, behave and perform in the mobile version of OMEGA and demographic and gaming-related factors (i.e., gender, age, educational level, academic/job-related background, gamer type, preferred game genres, hours per week for playing computer games). In addition, a data-driven profile for players of the desktop version of OMEGA and players of the mobile version of OMEGA will be created and compared. We expect to find interesting results from investigations into how users play OMEGA as well as the comparison between the desktop and mobile version of OMEGA.

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