Improving Game-Based Learning Experience Through Game Appropriation

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Abstract

Computational Thinking is an essential concept in this technological age. Several countries have included this subject as part of their educational program, and many others intend to do it. However, this is not a regular subject like maths or history; it needs more training (to increase the capabilities/skills) than studying and memorizing concepts. So it comes clear that the introduction of Computational Thinking to students requires the choice of the most suitable learning resources. Game-Based Learning was proven to be an effective teaching method. Therefore, we elected games as our learning resources. Nonetheless, we believe that the learning experience and motivation of students when playing games can be improved by choosing the most suitable game for each student. So, this paper focuses on the adaptation of Game-Based Learning to each student to develop Computational Thinking. We will argue that this adaptation can be done in a computer supported systematic way. To make that possible, on one hand, it will be necessary to classify games – an original ontology was used for that. On the other hand, it is crucial to establish the students' profile, having into consideration sociodemographic factors, personality, level of education, among others. Then, resorting to a similarity evaluation process it is feasible to choose the games that best fit the players, augmenting the effectiveness of the learning experience. We intend to start applying our approach – training Computational Thinking – to young students, since the first scholar years. However, we are also considering its application to adults starting programming studies.

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1 Introduction

With the advances in technology in the past years, Computing become an area of great interest and present in almost every day life activity and jobs. Consequently, an increasing number of students choose to access Computer Science courses, and many professionals are changing careers or starting a late education in technological areas. With this popularity and being programming a field in which students present several difficulties, it emerged the

need to explore the education of Computational Thinking. Multiple researchers believe there is a gap in the school systems that should be filled with the development of Computational Thinking, as this is a mental process to solve problems, beneficial in a variety of fields like math, engineering, and computer science [13, 15, 25].

Computational Thinking is a problem-solving model that, as the name implies, can be described as a way of thinking. To its development, a variety of concepts need to be mastered, and mental training is required. This type of mind reconversion can be difficult, making its introduction from a young age beneficial. Consequently, this led researchers to believe that Computational Thinking should be taught since kindergarten [15, 26]. Nonetheless, even with children, there are multiple obstacles to overcome. To successfully develop Computational Thinking it is fundamental to adopt suitable evaluation methods, school programs, and learning resources. A learning resource, to be efficacious, should be selected based on the subject and even the student in question.

Games were always attractive to young and even older people, since early years with traditional games to the more common digital ones. Therefore, it makes sense to explore multiple purposes for games than just entertainment. With this, Game-Based Learning appeared and was already proven to be useful in various researches [10, 23]. The increasing popularity of games and multiple characteristics and learning principles embedded in them led us to opt for this method to develop Computational Thinking.

Despite games being already a fun activity, we believe it is possible to boost students' motivation and learning experience from games by choosing the most suitable for each student. As different people have distinct tastes in clothes and food, it should be expected to have distinct preferred game types and learning styles. Therefore, makes sense to analyze what games are best for each individual and to implement that knowledge in the classrooms. For this to be achievable, first needs to be defined a classification for games, in order to have different game types to match with the players. To characterize the different aspects of a game, an ontology is being constructed. Secondly, it is necessary to draw the students' profile having into consideration various aspects like age, gender, country, education level, and personality features. If we connect the profile with game characteristics it should be possible to establish a pattern between players and game types.

Considering that, with age, people tend to have more difficulties in changing the way their minds process information, it is even more crucial to establish the best way to teach Computational Thinking to adults. Therefore, it is essential to analyze the differences between adult and young learning and what are the main challenges that condition adults. Few researches were made to examine the effects of Game-Based Learning in adults [4, 6]. Nonetheless, we believe this method can also be effective on older ages, especially if the person profile is taken into account, as it will evidence the factors that have an impact on adult learning.

This paper after the Introduction is organized in six sections. Section 2 presents research work on Computational Thinking. After that, Section 3 reviews the Game-Based Learning approach and discusses its use for developing Computational Thinking. In Section 4 the ontology, created by this team for the classification of games, is introduced and depicted in the form of a conceptual graph. In Section 5, a central one in our paper, it is discussed how player's profile relate to the enjoyment of games, and the consequent impact on the students learning result. Also in this section, we discuss the way we intend to follow to adequate games to students' profile. Section 6 discusses the factors that need to be considered when applying this approach to adult learners. The paper is concluded in Section 7.

2 Computational Thinking

Computational Thinking (CT) was first defined as a method for solving problems, designing systems, and understanding human behavior, based on fundamental computing concepts [26]. Later on, a new definition was given for CT, being "the thought processes involved in formulating a problem and expressing its solution as transformations to information that an agent can effectively carry out" [25]. With CT solutions are systematically formulated and with enough clarity that we can instruct a machine to execute them [15].

CT is a model of problem-solving, similar to the Scientific Thinking, and comprises a series of processes, approaches, and attitudes [7, 15]. The development of these concepts leads to an improved thinking process and enhanced solutions for a problem.

The processes involved in solving a problem are [7]:

- **Logical Reasoning:** use the existing knowledge to predict the behavior of a system.
- **Algorithm Design:** create a sequence of instructions to solve a problem.
- **Decomposition:** break down complex problems or processes into simpler parts.
- **Pattern Recognition:** identify similarities between problems and apply the same solution to solve them.
- **Abstraction:** remove unnecessary detail, identifying the essential information to solve a problem.
- **Evaluation:** prove that the consider solution is suitable for solving the problem in question.

It is essential to emphasize abstraction, as it is the most important process in CT [26]. With abstraction we can overcome complex problems, as we can use it to define patterns and, on the opposite side, to generalize specific instances. Computing is nothing more than the automation of abstractions, as we first solve a problem using CT, and then implement/automate the solution on a computer.

As for the approaches that characterize CT, there are [7]:

- **Tinkering:** experiment different strategies.
- **Creating:** design with creativity.
- **Debugging:** find and fix errors.
- **Persevering:** be persistent when facing obstacles.
- **Collaborating:** work as a team.

Lastly, when using CT one should assume the following attitudes [15]:

- **Confident:** trust in one's capacity to overcome problems.
- **Communicative:** communicate with others to discuss possible solutions.
- **Flexible:** deal with changes in the course of solving problems and accept open-ended problems.

Technology is present in almost every part of our lives and is necessary in a large variety of professions. Therefore, it is essential that everyone understands the bases of computation, so they can make the most out of it. This brings to the belief of many researchers, which is that everyone can benefit from the development of CT [15, 25].

CT includes a set of skills, attitudes, and approaches that are fundamental, universal, and transferable [15]. Therefore, the development of CT leads to a better understanding of multiple areas like math, engineering, and physics, due to the higher capability of solving problems, expressing solutions, and making abstractions. On a more obvious subject, CT leads to the improvement of computing capacities, which can promote the better performance of Computer Science students. These advantages led to multiple researchers promote that

CT should be taught in K-12, this is, since kindergarten to secondary education [26, 13, 15]. The early introduction of CT comes from the belief that a young mind can be easier modified, making the development of CT more effective. Furthermore, the interdisciplinary of CT is useful at this stage, since in preschool and elementary subjects are taught to the students combined [15].

Being such a mind-changing process, some issues are raised when trying to introduce CT in schools, like what concepts can students thoroughly learn and educators can properly teach, and at what level should the computer be used to do so [26]. Therefore, it is essential to thoroughly analyze details like the learning resources that should be used, and the evaluation methods. For this, it will be analyzed Game-Based Learning as an alternative to develop CT.

3 Game-Based Learning

Nowadays, games are not just for entertaining and a way of spending free time. More and more, researchers and professionals see the advantages of using games for serious purposes. On health and rehabilitation, games are being used to increase physical exercise and as a therapy treatment [6]. In a similar field, games are useful for training the brain, especially on older adults, improving reasoning skills, memory, concentration, alertness, among others [6]. As for business games, these are used to train professionals and can be a good ally for companies [6].

On education, a game can be used as a Learning Resource (LR). LRs are instruments of presentation and transmission of educational subjects. With LR it is possible to put in practice previous knowledge, acquire new knowledge, increase motivation, develop creativity, along with other advantages [3]. These resources can consist of images, maps, diagrams, articles, books, games, posters, among others.

Games are a big part of many students' life, as some spend hours of their free time playing them. This and other factors of students' daily routines, embedded with technology, can lead to a lack of interest in school activities. The traditional learning tools are not stimulating enough to hold their engagement, even becoming outdated [20]. Therefore, Game-Based Learning (GBL) emerged as a strategy to motivate students, being a concept extensively explored by researches [23]. GBL is a technique where games are used as LRs to develop a specific topic, allowing the subject to actively learning. Playing a game leads to learning due to a series of learning principles embedded in games that are activated while a person plays [11, 20]. For accessing a complete list of these principles fully detailed, one should consult the 36 Learning Principles defined on *What Video Games Have to Teach Us About Learning and Literacy* [10]. Some of the most important principles enunciated by multiple researchers are [11, 10, 20]:

1) apply previously learned knowledge, leading the student to develop prior learning;
2) use the feedback given about the student's progress/mistakes, helping him to overcome a difficult problem and to get excited when achieving results in the game;
3) employ the same approach to solve different problems, leading the student to develop problem-solving capabilities;
4) try multiple techniques to solve a problem, learning through practice, failure, reflection, and repetition;
5) interact with other, encouraging unity in a team environment.

These Learning Principles defined in games bring even more sense to the use of GBL to develop CT. For instance, similarities can be found between the items previously described and CT concepts. Items 1 and 3 are related to Pattern Recognition, as previous knowledge is

applied and transferred between problems. Item 4 is associated with Evaluation and Critical Thinking, as it is done experimentation and evaluation of results. It is also worth to mention that, as a game is an immersive activity, it can be more powerful to improve the thinking process. Brain training games are one example of a similar application targeted to develop the mind [6].

Various studies were conducted regarding GBL and its effects on students. Multiple researchers even concluded that this method can be more motivational and more effective for most students to retain knowledge [11, 12, 23]. Nonetheless, GBL should be a complement to the current learning system and never a substitute. For its proper use, it is necessary to ensure students are motivated by the games themselves and not just the competition between peers and that students can obtain knowledge by playing a given game.

Additionally, GBL can also be used as an instrument in adult learning to teach older students, benefiting both learners and facilitators [4, 6]. The majority of the conducted studies have focused on children, teenagers, and young adults [6]. Nonetheless, there has been a growing interest in the potential of GBL on adult education and informal learning, due to the increase of both the life expectancy and the number of adults engaging in learning experiences post K-12, but also the influence of technology on the daily life.

However, with the introduction of technology and games in adult classrooms, some difficulties may arise. For instance, difficulty with acceptance by older users since playing games may also imply having too much "fun" and lack of seriousness in the classroom [1]. In addition, difficulties with interface devices (particularly those with small buttons or writing) that may be challenging for adults with a mobility or visual impairment [6]. Lastly, a considerable period of adaptation since "Adults who have not been familiar with the computer in their youth and who are not scientifically oriented tend to be a little overanxious about using one" [17]. This subject will be further explored in Section 6.

4 Game Classification

Numerous aspects can be considered when defining a game. Among the different categories, some are of easy decision, as others can vary depending on the person classifying the game [5]. On all these aspects, the one that raises more discussion is the game genre. Various researchers and game designers came up with different possibilities of game genres, being complicated to reach a consensus. For example, game designer Tracy Fullerton [9] divided games into action, strategy, role-playing, sports, racing/driving, simulation/building, flight and other simulations, adventure, educational, children's, casual, and experimental. On a research to establish the connection between genres and usability of video games it was used a set of 6 genres to categorize games, being them [22]: role-playing games (RPGs), sports/racing, first-person shooter/tactical shooter, action, strategy, and adventure. Although many variations, a set of genres are very common in different classifications, like action and strategy.

To develop a proper classification for games, we believe the best method is to construct an ontology. Vastly used by researchers and companies, ontologies are an efficient approach to describe a domain. Therefore, *OntoJogo* (Figure 1) is an Ontology that is being created for Game Classification based on already existing ontologies for games like the ones presented on references [28, 5, 16].

At this point, the ontology divides games into digital and non-digital. Both of these types have some features in common. Therefore, a *game* can be defined by *player number*, *genre*, *story progression*, and *game mode*. The *player number* is presented as the accepted

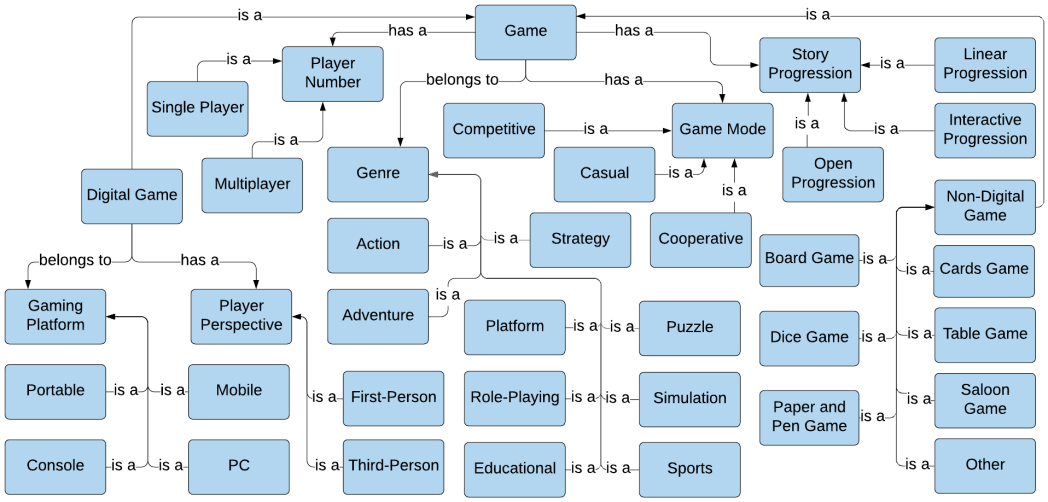

Figure 1 *OntoJogo*: Ontology for Game Classification.

way of *single-player* or *multiplayer*. As for *game genres*, we opted to divide them into *action*, *adventure*, *educational*, *platform*, *puzzle*, *role-playing*, *simulation*, *sports*, and *strategy*. As said before, genre is not an easy category to establish, being this the set that makes more sense for the work being done. The *story progression* refers to the level of exploration the player can do in the game and how the player's actions can impact the narrative. In a *linear* game, the player is fully oriented throughout the narrative, for example, by crossing levels. Therefore, the end and progression is equal for every player. When playing an *interactive* game, the end of the game can be different depending on the player's choices. The player still has a guidance but is always presented with possibilities to pick. On the other extreme, in a *open* game, the player can do what he feels like doing, not having any orientation and facing infinite possibilities. Finally, the *game mode* indicates the type of objectives the player intends to achieve. Depending on the *game mode*, the player posture should differ. In a *casual mode*, there is no competition, and the player can have a more relaxed attitude. In a *competitive mode*, the player is facing adversaries, being expected for him to try and win the game. In a *cooperative mode*, the player should make his best have a team spirit and be social.

Digital games is one that implies the use of technology. This type of game has as features the *gaming platform* and *player perspective*. The *gaming platform* can be *console*, *PC*, *mobile*, and *portable*. As for the *player perspective*, it is related to the player's perception of his character. In a *first-person* perspective, the player can not see his character and has a perception of the environment similar to the real world. In a *third-person* perspective, the player observes his character, creating an extra mental distance between him and the game. *Non-digital game* is one that does not require any technology, being more traditional. At this point, we divide this type of game into *board game*, *dice game*, *cards game*, *table game*, *paper and pen game*, *saloon game*, and *other*. *Saloon game* is the type that does not require any artifact, like a game that only involves singing or talking. The concept *other* was included for non-digital games not considered on the ontology, as a complete definition of this category could be very extensive.

These were the characteristics we believe to be more impacting on the player experience. Additionally, it is relevant to have in mind that most of the categories' options are not exclusive. For example, a game can be cooperative and competitive at the same time if players are part of teams competing against each others.

5 Games and Players Profile

As stated before, to use games as educational tools, it is essential to guarantee students are motivated by the games they play. For this, it is necessary to understand what are the factors that motivate each student and how to hold that motivation through time.

Examining first the part of maintaining the student motivated, it is interesting to analyze the *flow* concept. *Flow* is the optimal experience, where the subject lies between boredom and anxiety, not leading to either of the states [8]. When a player reaches this state becomes fully absorbed in the game. To achieve the state of *flow*, some characteristics are essential for the game. For example, the game must have clear goals and provide enough feedback [8]. Additionally, the level of customization in the game, although not required, can also have an impact. The more a player can manipulate characters, the more he constructs an identity, feeling motivated to keep playing for longer periods [11].

Aside from keeping a student motivated, it needs to be analyzed why that motivation appears in the first place. The most usual method to aboard this problem is by introducing questionnaires. Different approaches can be applied with questionnaires: open response surveys on what motivates the player [14]; closed response surveys about the player's motivation in a specific game [18, 27]; observation of the player's behavior while playing a game [24]. All these methods have the purpose of making a connection between the players' profile and types of games that motivates them. This connection is significant not just for the motivation factor, but to understand if playing a particular type of games can have a positive or negative effect on a person. An example of this is the revolt towards violent games. Some suggest that instead of concluding violent games turn the players more violent, it should be analyzed if the players that choose them already tend towards violence. This means that instead of negatively labeling a game, we should try to conclude if the game is suited for all players [18].

A traditional approach to analyze players is by establishing player types. One of the most popular and used categorization divides players into four different classes [2]: achievers, explorers, socializers, and killers. Although very acknowledging, some consider it not the best system to use in research, as it was never proven the player types to be independent. Furthermore, as player types are often defined with one personality trait on focus, it could lead to bias results [18, 27]. On a different strategy, one can analyze several aspects of the person, including age, gender, and personality features. Some researches were done to examine gender and age as influencing factors on players' motivation. For example, on Yee [27] work, conclusions were made on gender differences on social and achievement components. To examine the personality of the student, a possible approach is the Five-Factor Model of personality, which consists of analyzing the following traits [24]: openness to new experience, conscientiousness, extraversion, agreeableness, and neuroticism.

Although some work was already done on the subject and some conclusions were made, there is a need for future research to establish a connection between players' characteristics and the enjoyment of playing games [24]. For this, more features of the player should be considered, namely: sociodemographic factors like age, gender, nationality, level of education, family members, among others; personality factors like persistence, socialization, positivity, among others; and previous experiences with playing games.

To relate games with players, we intend to use the presented ontology, *OntoJogo*, together with a questionnaire for profiling players. A web platform will be developed to take advantage of these resources. Games and students should be registered in this platform, and the reaction of each student to a particular game should be recorded. With the accumulation of results, and resorting to pattern recognition and machine-learning algorithms, it should be possible to determine what are the most suitable games for each student.

6 The Bridge Between Young and Adult Learning

As mentioned previously in Section 3, GBL can also be used as an advantageous instrument in adult learning and education, possessing however its own set of difficulties over K-12 regular school. Therefore, when looking to expand GBL to older learners one has to consider the particularities of adult learning and its differences over young learning in order to successfully adapt the extensive research, programs and materials already available to serve older audiences.

Foremost, when talking about adult learning and education it is important to distinguish said concepts. Adult Education refers to the teaching of adults, that is, instructing/giving lessons to adult students with the involvement of a teacher and according to a curricular program, guide or plan of education. On the other hand, Adult Learning refers to the continuous process of learning and developing skills and knowledge throughout an adult's life.

Another related concept of extreme relevance when it comes to adapt GBL to adults is literacy. According to the OECD's (Organisation for Economic Co-operation and Development) PIAAC study (Programme for the International Assessment of Adult Competencies) literacy is defined as *"the ability to understand and use information from written texts in a variety of contexts to achieve goals and develop knowledge and potential"* [21]. It is important to take into consideration the student's level of literacy in order to be able to identify and apply the games more suited to its skills, since literacy among adults varies from an extensive range. The PIAAC study defined 5 proficiency levels that can be use as guide to the categorization of games according to this parameter. The levels are as follows [21]:

- **Level 1:** Lowest level of literacy. People at this level must be able to recognise basic vocabulary, determine the meaning of sentences and read short texts.
- **Level 2:** Ability to make matches between the text and information, paraphrasing or low-level inference.
- **Level 3:** Knowledge and skill in interpreting and constructing meaning across dense or lengthy texts; identifying, interpreting and evaluating pieces of information at various levels of inference.
- **Level 4:** People who display ability to integrate, interpret, synthesise, infer from complex or lengthy texts; apply background knowledge and identify and understand non-central ideas in texts.
- **Level 5:** Maximum level of literacy. Knowledge and skill in searching for, integrating, synthesising and selecting key information across multiple dense texts; making high-level inferences.

Lastly, regarding the differences between young and adult learning, there are two main models of learning assumptions: Pedagogy and Andragogy. Pedagogy (from the Greek meaning *"child leading"*) is defined as the art and science of teaching children and Andragogy, in opposition, is defined as the art and science of teaching adults [19]. Knowles [19] compares Pedagogy's and Andragogy's assumptions regarding the concept of the learner, the role of the learners' experience, readiness to learn and orientation to learning, allowing for a better understanding of both models. The comparison is as follows:

- **Concept of the learner:** In Pedagogy the learner has a dependent role whereas in Andragogy the learner matures from dependency to self directedness.
- **Role of the learners' experience:** In pedagogy the learners' personal and life experience is of reduced importance. In Andragogy, the learner's experience is valued, adults attach more meaning to learn they gain from experience.

- **Readiness to learn:** In Pedagogy students are willing to learn what is decided they should, and most are capable of the same learning that of their peers whereas in Andragogy students are willing to learn that which will help them on their real-life problems.
- **Orientation to learning:** When it comes to Pedagogy, learners are subject-centered in their orientation to learn. On the other hand, in Andragogy, learners are performance centered and see education as a process of developing skills to better their life.

In addition to the concepts stated above from an educational perspective, it is also essential to take into account the student's profile. Since adults have a more structured personality than young students, considering their profile when applying these new teaching/learning methods could be decisive to their effectiveness.

7 Conclusion

The difficulties found in general by young people and adults to solve problems manually or by computer could be overcome by training Computational Thinking. Since this is a mind process, the earlier this training occurs the easier it is to have a positive effect on problem solving activities.

Guided by this belief, we started a research project aimed at finding ways to realize the referred approach. First of all, we discovered that the choice of accurate learning resources is a crucial step. Because Game-Based Learning is an immersive activity, we considered it to be an effective way to motivate students and change minds. That feeling proved to be true after a careful literature review. However, games used as learning resources must be carefully chosen to fit properly in the students' profile. For this effect, we proposed an ontology to classify games and a series of features to have in consideration when analyzing the students' profile. In addition, it is also necessary to determine how Computational Thinking can be developed in older ages. In this paper, it was given a perspective on how Game-Based Learning can be employed in adults. Furthermore, it was analyzed what differs between young and adult learners, and how the use of proper resources for each student can also be beneficial to deal with this matter.

As future work we intend to develop the questionnaires to identify the students' profile and to determine the appropriate similarity algorithms capable of finding the connection between them and games.

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