A Collaborative Game for Learning Algorithms

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Abstract: Educational games constitute an important mean of delivering effective learning procedures to students and they can offer various learning opportunities in all levels of education. In this work, we present a collaborative game that was developed to assist students in learning algorithms and we explore its learning capabilities. The game aims to assist students in learning constraint satisfaction algorithms and it is based on the map coloring game. In the context of the game, students can experiment and apply the algorithms in various learning activities and training scenarios. The game has been integrated into the curriculum of the artificial intelligence course in our university. An evaluation study was conducted in real classroom conditions and revealed quite promising results which indicate that the game is an effective way to enhance students' motivation, engagement and interest and also it helps students to deeper understand the functionality of constraint satisfaction algorithms.

1 INTRODUCTION

The rapid development of educational technology has brought new tools that can be used in the educational process. Indicative examples are the educational games which are a rapidly growing field and offer various possibilities for innovative educational activities. One of the main features of educational games is that they can offer pleasant and attractive educational activities to users and can attract their interest and also can cultivate and strengthen their motivation for learning (Burguillo, 2010; Dickey, 2011; Ebner and Holzinger, 2007)

The educational games are a rich learning environment and offer diverse and effective ways of acquiring knowledge. In an effort to attract and engage students and enhance the overall efficiency of learning procedures, digital technologies and computer educational games are examined to add fun factors and make teaching more attractive, appealing and most of all, efficient (Mihail et al., 2013). In our days, a great part of the students, like most individuals, spend a large part of their free time playing computer games and in this line the integration of games into curriculum of a course could increase students' interest and stimulation and provide opportunities for learning in an entertaining way.

Educational computer games can be used to teach the area of computer science and researchers point out that they could constitute an effective way to provide more interesting learning environments for knowledge acquisition and construction (Sung and Hwang, 2013). Educational games have been used successfully in both introductory computer science courses and general artificial intelligence classes to scaffold learning and bring excitement and enthusiasm among students (Bayliss 2007; Parberry et al., 2005; Sosnowski et al., 2013; Taylor, 2011; Wong et al., 2010).

Collaborative learning is a term for a variety of educational approaches which involve more than one player in the playing of the game with the pedagogical intention to promote cooperative learning between those engaged in the game (Dickey, 2007). Studies point out that students learn more effectively when they collaborate with each other (Abid et al., 2016) and in this context, collaborative games have an important role as highly efficient and engaging learning environments (Prensky, 2007). Collaborative educational game-based learning can have a substantial benefit on students learning mainly by promoting positive learning attitudes and high learning motivation (Romero et al., 2012; Sung and Hwang, 2013). In addition, collaborative learning in the context of educational games can also improve

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students' learning achievement, their self-efficacy owing to the provision of knowledge organizing and knowledge sharing embedded in the activities of the collaborative gaming environment (Sung and Hwang, 2013).

In higher education, the educational games are pointed out to be an effective approach to assist students' learning. The integration of educational games into the curricula of university courses can provide the means of attracting students interest, better and deeper engage them in learning activities and improve their knowledge construction (Ebner and Holzinger 2007; Hatzilygeroudis et al., 2012). Algorithms constitute one of the most fundamental domains in computer science discipline and it is important for students to get a deep understanding of their functionality. In artificial intelligence curriculum, search algorithms and constraint satisfaction algorithms are two important topics that students come across and learn. It is considered necessary that students learn efficiently and in depth the way that algorithms function and also be able to accurately apply them in various problems and situations. However, the domain of search algorithms is acknowledged by many tutors to be a difficult domain to teach and also a very hard and complex domain for students to deeply understand and correctly implement (Grivokostopoulou et al., 2016; Naser, 2008). Indeed, the domain consists of complex cognitive and error prone processes that traditional education fails to cover and efficiently teach.

In this paper, we present a collaborative game that assists students in learning algorithms and explore its learning capabilities. The collaborative game aims to assist students cooperate in learning algorithms and apply them in various learning activities and training scenarios. The game assists students in learning constraint satisfaction algorithms and has been integrated and used into the curriculum of artificial intelligence course in our university. The evaluation studies conducted revealed very promising results and indicate the games to be an effective approach and to assist students in deeper and more complete learning algorithms and also to enhance students' motivation and engagement with educational procedures.

The reminder of the paper is organized as follows: Section 2 presents related work on the utilization of educational games into course curriculum while Section 3 presents the collaborative games developed and used to assists students in learning algorithms. Section 4 presents the results from the experimental evaluation and discusses the learning efficiency of the game and the students' experiences with them. Finally, Section 5 concludes the paper and provides various directions that future work can focus on.

2 RELATED WORK

The design, development and integration of educational games in courses' curriculum have attracted over the last years the attention of the researcher community. Various works point out the important role of educational games in assisting students' learning and improving the learning efficiency of educational procedures. A detailed and complete overview of approaches can be found in (Michael and Chen, 2005, Connolly et al., 2012, De Gloria et al., 2014, Gibson and Bell, 2013). In literature, there is great research interest and many works study the design of educational procedures and the development of games for teaching the domain of computer science.

In (Markov et al., 2006) the N-Puzzle game is used for teaching state-space search and machine learning. The popular Pacman game has been used in order to formulate educational versions of it assist students in learning search algorithms functionality (Grivokostopoulou et al., 2016). Indeed, Pacman game is utilizing in the introductory artificial intelligence course at Berkeley University for teaching AI concepts such as state-space search, adversarial search, Markov decision process and probabilistic tracking (DeNero and Klein, 2010). Furthermore, the Rook Jumping Maze has been used for teaching uninformed search, stochastic local search and machine learning (Neller, 2011). A common characteristic of the above efforts is that games are mainly involved in AI programming projects. A project is designed based on a game that asks for implementation of algorithms concerning state search, reinforcement learning, etc. The game acts as a motive for the students to make the implementations. Another effort is presented in (Chang et al., 2008) where a game-based learning approach is used to help students learn graph theory topics and more specifically Kruskal's, Prim's and Dijkstra's algorithms. The game is called Ticket to Ride and the students through the missions that they choose about connecting one city to another, come across the implementation of the above algorithms. In additional, COPS (Collaborative Online Problem Solving) (Bachu and Bernard, 2014) is a web based strategy game that assist the students improve their problem solving ability by building program flowcharts as a jigsaw puzzle. In the game, students through the visual representations of the problem's

solutions and can follow more easily the logic in their solution.

3 COLLABORATIVE CONSTRAINT SATISFACTION EDUCATIONAL GAME

Constraint satisfaction (CS) is a general approach for solving problems, which can be expressed as constraint satisfaction problems (CSPs). A CSP is defined as: given a finite set of variables, together with a finite set of possible values that can be assigned to each variable and a list of constraints, find the values of the variables that satisfy every constraint. The map coloring problem is a famous problem that can be modelled as a Constraint satisfaction Problem. In this problem, a map consisted of a number of regions is given and we need to color each region of the map with one of a given set of colors in such a way that no two adjacent regions have the same color. A simple map coloring problem is illustrated in Figure 1. The map consists of four regions that are to be colored with three colors: red, green or blue.

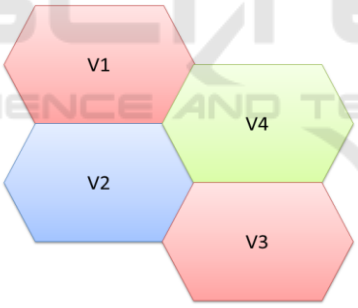

Figure 1: A simple four-region map-coloring problem.

The problem in Figure 1 can be represented as a Constraint satisfaction Problem as follows:

Initially, we define a set of variables V where each variable represents a region in the map. In the example case of Figure 1, is define as: V={V1,V2,V3,V4}.

Then, we define a set of value domains D where each domain includes the values that corresponding variable can take. In our case: D={D1,D2,D3,D4} and D1=D2=D3=D4={red, green, blue}.

Finally, we define a set of constraints C where each constraint represents a relation between variables of the problem. More specifically, in the example case of four map coloring problem C define as , C={C12,C14,C23,C24,C34}, where Cij ≡ Vi≠Vj (that is each region represented by its corresponding variable has a different color/value from its adjacent region)

Associated with every CSP is a constraint graph. The constraint graph contains a node for each variable and an edge between each pair of nodes for which there is a constraint between the corresponding two variables. Figure 2 represent the constraint graph for the four region map coloring problem where each edge represents two adjacent regions in the map.

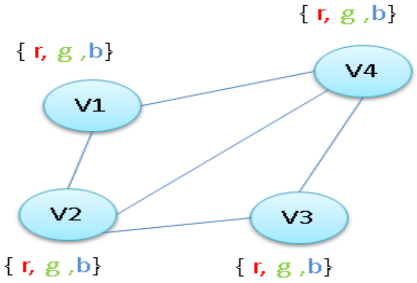

Figure 2: A simple four-region map-coloring problem.

The coloring game has both single player and multiplayer modes. The objective of the game is similar for the two modes. The player has to color a map, using a set of available colors so that adjacent regions of the map do not have the same color. The complexity of the generated maps (number of distinct areas) and the available colors set are parameterized. The collaborative game aims to assist learners to realize and better understand through the game the concept of constraint satisfaction during problem solving and the educational process.

Initially the students can determine the complexity of the problem to be solved. They can either decide by themselves on how many colors they think are adequate for solving the problem or can choose one of the three available difficulty levels (easy, medium, difficult).The determination of the level of difficulty of each map based on the number of colors that the map needs to be resolved and the maximum number of areas bordering each region. A screenshot of the multiplayer coloring map game on a simple case is illustrated in Figure 3.

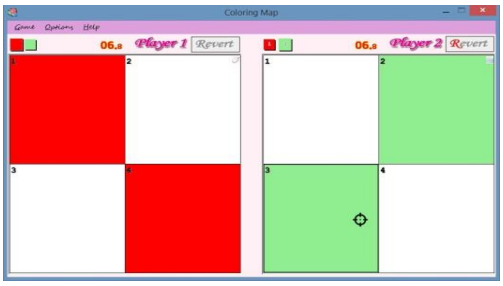

Figure 3: Map-coloring problem Multiplayer game.

In the first level of the game, students use additional colors beyond the minimum required. In the second level, one additional color is used and in the third level the minimum number of colors is used, thus making the game more difficult and challenging to solve. The latter is concerned with whether the user chooses from the set of all available colors for each area, or the system filters the colors that cannot be used (i.e., propagates the constrains, in other words makes an AC-3 step). Also, for each option of the player, it creates the appropriate tree structure representing the regions, the coloring steps taken and how propagation of constraints as presented in Figure 4. In this way, the student can get a useful model of how the constraints are propagated, which is an important and fundamental characteristic of CSPs. Furthermore, a student can step back to previous states (of the solution path), a process known in search algorithms as backtracking. Backtracking is in several cases a difficult to grasp aspect of search algorithms. Using the game, the student can see it in practice while playing. Also, the students can solve the problem as many times as they want and find different or better solutions, by learning the constraint satisfaction algorithms. Different color combinations can produce sets of different solution paths. Additionally, the game calculates the student's score, which is determined by the difficulty level of the problem, the students' actions and the time taken to solve it.

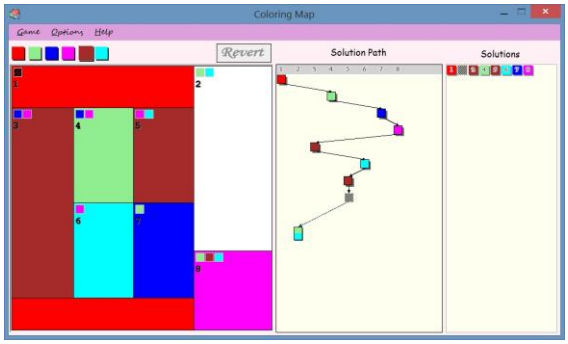

Figure 4: Treestructure of Map-coloring problem.

Playing with the game, students unknowingly become familiar with concepts like constraints propagation, backtracking, multiple solution paths and others by actually emulating steps used by a search algorithm. This can greatly facilitate teaching of the theory behind CSP solving and corresponding algorithms, finally, they can use the game again to test the obtained knowledge on algorithms and experiment with them, working out their differences and details. This can be easily done, given that really the game can take on many different configurations and make multiple trade-offs between complexity and fun factors. Of course, the tutor could specify different scenarios to make learning more directed and avoid useless playing.

4 EVALUATION

We conducted an experimental evaluation study in the context of the artificial intelligence course in our university. The purpose of the experimental study was to evaluate the learning effectiveness of the collaborative game and identify students' attitudes, perceptions, and usage-intentions toward learning with them.

4.1 Method

In the context of the evaluation study, we compared learning with the collaborative game versus the learning with the single player game. The participants in this evaluation study were 100 undergraduate students (both female and male) that were enrolled in the artificial intelligence course. They were in the 4th year of their study and their age ranged from 21 to 24 years. In the context of the study, a pre-test / post-test experimental procedure was followed. Initially, the participants of the study were randomly assigned to two groups (control vs experimental) and so, we created two groups that were named GroupA and GroupB respectively. The first group, GroupA, consisted of 50 students, where 22 were female and 28 were male, and the second group, GroupB consisted of 50 students where 23 were female and 27 were male.

We followed a pre-test, post-test study design followed by a questionnaire survey to assess the learning effectiveness, the learning attitudes and the motivation of students and also for gathering students' attitude, opinion and experiences about the collaborative game. The students of the GroupA, which constitutes the control group, learned with the educational game as a one-player game. Students of

GroupB, which constitutes the experimental group, were given access to use the collaborative game and to study the Constraint Satisfaction Problem. The experiment consisted of four main phases which are the pre-test, the learning phase, the post-test and the questionnaire phase used to collect students' thoughts, opinions and experiences about the game. The overall structure of the evaluation study is illustrated in Figure 5.

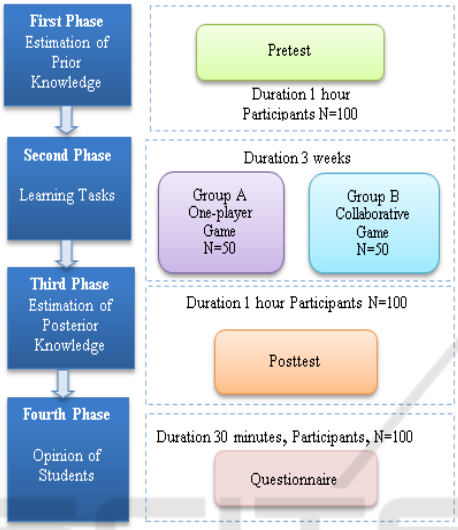

Figure 5: The overall structure of the experimental study.

The two groups followed the same procedure; both groups were given a pre-test and then GroupA learned about CSP algorithm with the single-player game, while the students of GroupB learned with the assist of the collaborative game afterwards, both groups were given a post-test. After the post-test, all participants were given a questionnaire to fill in. The pre-tests and post-tests were isomorphic and incorporated structurally equivalent exercises on CSPs and were conducted in the computer room of our department. After the learning activities the students were asked to fill in a questionnaire and express their affect, opinions and experiences towards the games and assess their learning assistance.

4.2 Results and Discussion

An independent *t*-test was used on the pre-test. The means of pre-test for GroupA and GroupB were 4.62 and 4.71 respectively. The results showed no significant difference among the students of the groups ($p=0.61 > 0.05$) so it was concluded the two groups had equivalent prior knowledge on the domain of Constraint Satisfaction before the experiment.

After that, an ANOVA analysis was performed. The ANOVA results indicate the differences in post-test scores are statistically and significantly different between the two groups ($F=142.4$ $p=0.00<0.05$). Finally, the results showed that the performance of the students of GroupB, who used the collaborative game, was better than that of the control group. Table 1 presents the post-test results, in which the mean values of the post-test scores were 6.41 for Group A, and 8.01 for Group B.

Table 1: Analysis of the Post Test Results.

Groups	N	Mean	SD
GroupA	50	6.41	0.65
GroupB	50	8.01	0.87

Subsequently, the students of the GroupA and GroupB were asked to fill in a questionnaire that included questions for evaluating usability of the one-player and collaborative game respectively, stating their experience and their opinions about the learning process. The questionnaire included 12 questions. The questions Q1-Q9 were based on the Likert scale (1: not at all, 5: very much). Questions 10-12 were open type questions and concerned strong and weak points of the educational games or problems faced.

Table 2: Results of the Questionnaire.

	Question	GroupA Mean	GroupB Mean
Q1	The games make the CSP more understandable.	3.88	4.46
Q2	The games assisted me in getting a deeper understanding of the functionality of the CSP after playing.	4.25	4.65
Q3	I enjoyed playing and learning with the games.	4.05	4.52
Q4	The games made me more active in the course.	3.95	4.16
Q5	The games can increase my motivation.	3.55	4.42
Q6	The games can enhance my engagement in the course.	3.45	4.43
Q7	The games can enhance my learning interest.	4.01	4.45
Q8	The using of the games for learning is more interesting than other ways of learning.	3.88	4.60
Q9	I suggest the games to be integrated into the course and be used by the next year's students.	3.5	4.46

The results of the questionnaire are very encouraging indicating the very positive attitude that the students of GroupB have towards the integration of games in the course curriculum. The questionnaire results showed that students of GroupB indicated that the games make the CSP more understandable to them (4.46) and that they assisted them in getting a deeper understating of the way that each algorithm functions (4.65). More specifically, students found the collaborative game to increase their motivation (4.42) and also to enhance their engagement in the course (4.43) and in addition to greatly enhanced their interest for learning (4.45). Also, students indicate that they enjoyed the integration of the collaborative game in the context of the course (4.52) something that made them also more active in the course (4.16). Furthermore, the results show that students found the games and learning with collaborative game very interesting and more interesting that other ways of learning (4.60). Finally, students suggest the collaborative game to be integrated into the course curriculum so that to be used by the students of next years (4.46).

The results of the experimental study shows that the attitude of the students towards the collaborative game was very positive and also that the game has great learning capabilities. More specifically, an interesting aspect of the study concerns the increase of students' engagement with the course and also the increase of their efforts in a very positive and enjoyable way.

5 CONCLUSIONS

With the great advancement of the technology, the educational games constitute an important mean of delivering effective learning procedures to students and they can offer various learning opportunities in all levels of education. Serious games can scaffold students learning and bring excitement and enthusiasm among students and most of all, assist them in learning more efficiently, in an interactive and entertaining way. In this work, we presented a collaborative game that was developed with the aim to assist students in learning constraint satisfaction problems and algorithms. In the context of the collaborative games, students can experiment and apply constraint satisfaction algorithms in various learning activities and training scenarios. The game has been integrated and used in the curriculum of artificial intelligence course in our university. An evaluation study was conducted in real classroom conditions and revealed quite promising results. The results indicate that the collaborative game constitutes an effective way to enhance students' motivation, engagement and interest and also help them to deeper and more completely understand CSP algorithms and their functionality.

The findings of the study provide various directions that future work can focus on. Initially, a bigger scale evaluation will be designed and conducted with the aim to provide a more complete insight of the learning efficiency of the game and also evaluate specific educational capabilities of them such as the feedback and the assistance offered to students. Another direction for future work concerns the integration of learning analytics mechanisms into the games that will record and analyse students' behaviour and actions during the learning activities.

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