Wizard of Oz in Designing a Collaborative Learning Serious Game on Tabletops

Mehrnoosh Vahdat, Sébastien George, and Audrey Serna

***Abstract*—This paper aims to introduce Wizard of Oz methodology as an effective method in testing a serious game design which is aimed at enhancing collaborative learning on tabletops. The interface design enables mixed reality over tabletops to engage the players effectively in the learning activities. Additionally, the serious game scenario has been created to learn traffic rules and signs inside a city. The Wizard of Oz methodology was employed to experiment the design. Both questionnaire and observation were adopted to measure three perspectives of the serious game: supporting collaboration, facilitation of learning, and validation of design. The results of experiment by Wizard of Oz show that this method is highly effective in measuring collaborative learning in the serious game design. Moreover, the qualities of interface design and game scenario are explored during the experiment.**

***Index Terms*—Collaborative learning, serious games, tabletops, mixed reality, wizard of Oz.**

I. Introduction

Preparing the learners for participation in a knowledge society is inevitable for education in the future. Computer-Supported Collaborative Learning (CSCL) is one of the revolutions of modern technology that enhance learning and teaching [1]. "Collaborative or group learning refer to instructional methods whereby students are encouraged or required to work together on learning tasks" [1].

Shah [2] discusses about the kind of collaboration which is actively carried out among a group of people and suggests guidelines to reach a successful level of collaboration. For instance, users must reach a mutual agreement or follow a set of rules to have a productive collaboration; and the system should allow users to negotiate their roles and responsibilities and assign authority, as well as exploring their individual differences.

One of the ways to enhance CSCL is through educational computer games. Serious Games (SG) are one of the effective ways in fostering education. By emergence of technology and computers in the field of education, and more and more familiarity with computer games, serious games are becoming famous as an innovative generation of learning technology. Reference [3] defines serious games as pedagogical multimedia products that help players to improve their skills and knowledge.

Educational games like any other games can be designed for one player or a group of people. Designing a game scenario for groups that enable collaboration for problem solving, would engage students in a shared activity in which they discuss and exchange information to reach a satisfactory result. Combining the features of serious games that increase students' motivation with supporting collaboration can result in a successful educational outcome.

There are various tools to be considered in a serious game design. In this study, the use of tabletops and mixed reality is explored as beneficial means to facilitate collaboration and learners' engagement. Digital tabletops have been popular for their rich interactive and collaborative features. Reference [4] illustrates the features of tabletops and describes that one of the key features of tabletops is their multi-touch interaction making collaboration easier. Additionally, their abilities to engage users in the group with verbal and face-to-face communication are their strong advantages; accordingly nowadays some scholars start using them for educational purposes. There is still a need to investigate about tabletops potential on learning outcomes and their use in various situations [5]. Studying diverse collaborative models on tabletops shows the potentials of this system to invent new approaches as in [5]-[7].

One of these potential new approaches considers the use tabletops to support mixed reality to favor learning. Indeed, mixed reality applications have been developed in many contexts such as games, education, and these applications use computer vision, as well as virtual and augmented reality techniques. Mixed reality is defined as "an interaction paradigm that seeks to smoothly link the physical and data processing (digital) environments" [8].

We work in a project which aims to develop methods for the design of serious games using mixed reality on tabletops. In this context, we focus on the design of a particular serious game to learn traffic rules and abilities of tabletops toward mixing the virtual and real environments are taken into consideration.

Based on the objectives of this study, the design of serious game follows principles of collaborative learning as well as tabletops interactive design that enables mixed reality. The guidelines regarding the collaborative learning on tabletops as in [9], [10], are considered to develop an innovative serious game for learning traffic rules and road signs. The main research issues focus on evaluating the design and justifying the methodology adopted for the evaluation. In the following sections, we show how this study addresses the following research questions:

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1) How could designing serious games on tabletops facilitate collaborative learning?
2) How could collaborative learning design be assessed?

II. Hypotheses and Research Methodology

There are several hypotheses introduced as the design qualifications and the Wizard of Oz is chosen as a method to evaluate these abilities. We considered the following abilities for the design of serious game which are experimented afterwards:

1) The serious game design supports collaboration: people can learn traffic signs and practice them together; they can ask each other what a sign means and how to react toward a traffic or road sign. Thus, this kind of task can be considered in a collaborative problem solving environment. Also, designing a serious game would foster the users' motivation, therefore raising their collaboration.
2) The serious game facilitates learning: The task of reacting to traffic rules while playing a competitive game perfectly matches the concept of serious games. Additionally, a combination of mixed reality and tabletops can improve the visual and tactile reaction and perception, and boost the learning process.
3) The serious game design is valid: The game scenario and the interactive design of tabletops is clear for the players and engage them in the process of collaborative learning. For instance, utilizing mixed reality is a valid choice for the design on tabletops. Moving a physical car on the tabletop and situating physical traffic signs would engage users better in the serious game's objectives.

To validate these hypotheses, we used Wizard of Oz (WOz) methodology which is well-known for exploring user interfaces for pervasive, ubiquitous, or mixed-reality systems that use complex technologies [11]. Recent technologies provide many possibilities for user interaction and involve sophisticated hardware and software applications. Therefore, developing a complete prototype would be usually very costly and time-consuming if designers evaluate their assumptions through building the systems [11].

Wizard of Oz is a rapid-prototyping method in which a human, who is called Wizard, acts as a computer and simulates the system's intelligence by interacting with the user via a real or mock computer interface. This method is very useful for testing the costly new technologies with innovative approaches to interface design [12].

In an iterative design process, there can be many cycles of brainstorming, prototyping, development, user studies, and assessment to be able to reach the final design. In this process, using the WOz technology is helpful to remove one or two cycles as well as save time and investment, especially in computer vision technologies that require heavy programming. Reference [13] explains that "Wizard of Oz tests are easy to arrange as field tests and the method is an invaluable tool for designing computer vision based action games".

In the context of our research, Wizard of Oz methodology is very advantageous to save time and eliminate the complexity of implementation. In this regard, a paper prototype has been prepared for each tabletop and a person as Wizard was considered to play the actions of the tabletop interface. As the WOz prototyping allows a true interactive experience without traditional programming [14], it is advantageous to perform the serious game without technical bugs and potential hardware and software problems. Another factor of this methodology is to trigger an analysis of interaction which leads to the development of new design ideas [14]. Since using tabletops for collaborative learning of traffic rules would be a new learning approach and developing the systems require having two tabletops with specific applications, the paper prototype would measure the usefulness of the design for learning and might add new design ideas to modify the game. This type of prototyping as in [14], would endorse collaboration and practical dialogue among users and designers and also the role of user is considered as a stakeholder in the development process.

The interface design and game scenario was tested in the experiment. Afterwards, the suggestions for design modifications can be implemented based on the way of collaboration. As in [15], designing collaborative interfaces for tabletops involves understanding of how groups manage their acts over a tabletop.

III. Serious Game Design

The issue of this work is to encourage collaborative situations and explore the potential of tabletops. In that way, we chose to implement two kinds of interactions between learners: competition and collaboration. The designed serious game is played by two teams as competitors. Each team members are required to collaborate together in order to defeat the other team and win the game. During the collaboration, players learn about the traffic rules and road signs. The game is designed to be played over two digital tabletops that enable manipulation of objects on a same city map; in this way players assign physical traffic signs and move tokens as physical cars.

The goal of the game is to collect the most money from the banks of the city in a limited amount of time and exceed the other team. On each map there is one car which has to respect the traffic rules and react to the road signs correctly to collect the money very fast. During a turn, the team has to move the car and use the features of the car (e.g. brake, accelerate, turn, and etc.) and then assign road signs together in order to bother the other team. Each team can change or add signs for the other group in order to make their situation harder and more complicated.

The Wizard of Oz method is used both in the design process and the experiment. During the design process, many tests were done by use of paper prototyping to modify the design and offer a final version for the experiment and final evaluation. The tests, done before the experiment, showed the complexity of game rules and offered solutions for the experiment to modify the rules and simplify the design. For instance, it was decided to have a mirroring tool instead of a meta-cognitive tool since tracking the actions and calculating their reflection at the same time is too complicated in the context of paper prototyping. The chosen mirroring tool is a

simple bar chart that shows the amount of errors committed and money taken by each team. The mirroring tool is visible on the bottom-right corner of the tabletop (Fig. 1).

Fig. 1. Paper prototype of a tabletop.

The following sketch (Fig. 2) shows the organization of tabletops and participants in the Wizard of Oz experiment. Based on the original design, there are two groups that compete with each other. Each team's members collaborate together to reach the best result. There are three players and one wizard on every tabletop. 'D1' and 'D2' are drivers and SI is the "Sign Indicator".

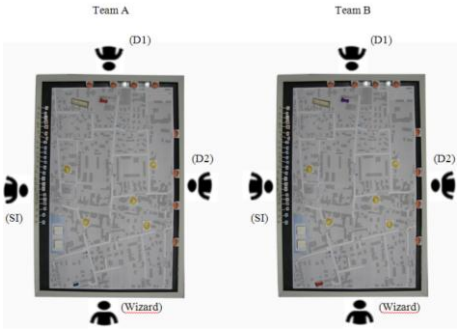

Fig. 2. Design sketch of two tabletops for the experiment.

'D1' and 'D2' around each tabletop are responsible to move the car and react to the signs, and the 'SI' is responsible to assign the signs on the tabletop. The fourth person is a wizard who must react as computers and reflect on players' actions.

As the experiment is done based on the Wizard of Oz methodology, the Wizards on each tabletop must be aware of all actions of tabletops, and that is quite complicated when human is involved instead of a machine. One of the challenges revealed in the tests shows that it is very difficult for the Wizards to take care of all the actions over all the tables and change at the same time on its own table. Changing the game to turn-based is a huge help to give time and care to the Wizards; but still there is a possibility that they make mistakes and cannot see and change everything in the game. Another consideration is that the tables should be close to each other so that the Wizards can see the changes on the other table and change on their own. In the real game on digital tabletops, the location of the tabletops would be far from each other but for the paper prototype experiment, we have to arrange the tables in a way to reduce the complexity.

The serious game is designed to facilitate a good level of collaboration, an engaging scenario, and the territory of tabletops allows a good level of coordination among the groups. There are physical tokens to provide the features of mixed reality. Monitoring is possible for all users because there is enough visibility of actions over tabletops, and also they can see what kind of action is taking place so they have transparency of actions as well. Additionally, the personal space of each user is visible to her/his team members, which raises the awareness. Alternatively there is no private space which is not an issue in the goal of this game.

The size of the tabletop is: 46.2 × 61 cm; based on the amount of tasks to coordinate and divide, users will not run out of the working space. On the other hand, in a cooperative learning task small spaces are suitable for the group activities involving tightly coupled collaboration [15]. The amount of people assigned in each group on top of one table is well-thought-out based on the size of tabletops as well as the game coordination.

In this design, participants are tightly coupled, since their actions are dependent on each other and they must interact frequently and dynamically to be able to react to the road signs. There is also mixed-focus collaboration involved to some extent because they have to switch between independent and shared activity although the independent activity here is not as intense as the shared one. Independent activity includes browsing the signs or features and deciding what to choose.

The game is mostly offering tight coupled group work rather than loosely coupled independent work. Users can search for indications of the signs in their personal space, but as they can share information and discuss, it is expected that they ask each other rather than searching for the information individually. Design of the shared spaces must decrease the interference. For instance, if the car is close to a sign, that sign cannot be removed or changed for one turn.

IV. Evaluation and Results

The experiment uses the Wizard of Oz methodology to assess the design and justify choices. Examining how drivers (four participants) and sign indicators (two participants) collaborate while playing the game and learn from each other is the main aim of this experiment.

The time for the experiment was considered as two hours.

Each player and wizard had a copy of relevant rules to refer to if needed during the game. And the summary of the rules was printed in A3 size and hanged on the wall to remind the major rules to the participants while playing the game. In addition, a video camera is installed on top of each tabletop to record the experiment.

The aim of this section is to sum up the results and compare with the hypothesis of this study. The design process and tools that are presented in this study intend to create a serious game with collaborative learning on tabletops. The experiment was planned in a way to assess the qualifications of design regarding collaboration, learning, and validity of design. Validation of design refers to the quality of design from both interaction and game design point of view.

Data has been collected from both observation and questionnaires. The questions were designed to collect both qualitative and quantitative data. The data from observation was reported qualitatively regarding three aims of the

experiment: exploring collaboration, learning and design. The data collected show that the game supports a high level of collaboration. For example, the results from questionnaire show that all of the six participants found the game collaborative. Five players stated 'A lot', and one checked 'A little' for the level of collaboration. Majority mentioned that they had a lot of discussion with their team members, and collaboration was very efficient in their team. Among them, one stated this level as 'Average'. Five of the collaborators believe that it is more efficient to play in a team rather than alone, just one player stated the contrary. There was a few or no misunderstanding among the team members concluded from their answers.

All the players were engaged in the discussions during the game and were following the activities enthusiastically. They were asking many questions from each other and for performing actions they discussed about possible strategies. In general, participants collaborated intensely during the game and found the way of team collaboration efficient in their performance. They discussed a lot during the game to reach agreements for actions, learn about the traffic rules, warn each other about the game's rules, and set strategies to defeat the opponent. As discussed before, communication is a required part of collaboration that facilitates the exchange of information [2]. As it was observed during the experiment, communication had a key role during the game in problem solving and decision making. Due to the successful collaboration model and from a comparison with the results of design experiment, we can include that that the serious game supplies a successful collaboration among players. The game has a clear face-to-face communication where each player has a role and specific authority to contribute to the collaborative environment, and all the actions of team members are tightly relevant and must be coordinated to reach a satisfactory result. Users are required to respect the rules of the game and reach a mutual agreement for each turn to reach a productive collaboration.

The results from observation show that a part of collaboration is done among the team members to decide about a strategy to reach the best results. Locating the correct signs on the road while following the game rules was the main cause of collaboration as can be seen in Fig. 3. Participants asked many questions from each other and asked help regarding the game rules, traffic rules and meaning of signs. Almost the whole time of the game, players were busy discussing with each other even between their turns. They tried to estimate their opponents' actions and reach agreement for their future activities. The results from questionnaire and observation show that the participants enjoyed playing the game and found the game scenario attractive.

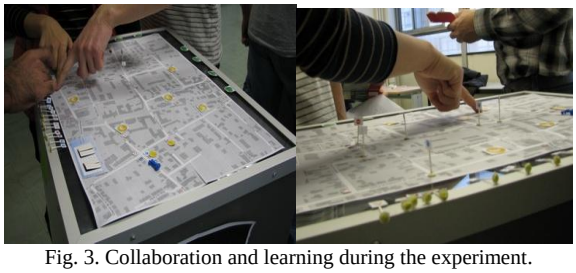

Fig. 3. Collaboration and learning during the experiment.

All the players had an active role in the game. They also showed a lot of enthusiasm. Sometimes they were laughing and making jokes about their actions which showed that they enjoyed playing the game. For instance, in the last turn, even though the red team knew they cannot get more points, they still liked to play. In general, the users felt comfortable asking about the meaning of the signs from each other. In the first half of the game discussions were more than the second half, because they needed to learn about the rules of the game and ask each other questions about the road signs they did not know. In future design stage of the game, it is suggested to apply more traffic signs so as to raise the discussion toward road signs' applications and meaning. Additionally, it is advised to have different set of road signs on each table, thus in all the levels of game users face various signs that they do not have on their table, and in each turn they have to discuss about the new signs.

According to the second hypothesis, it is required to examine whether the serious game design incorporates learning tasks for the players. Also, the collaboration to perform activities leads to learn the traffic rules. Based on the outcomes of observation and comparison of pretest and posttest, participants have learned about the traffic rules and signs via playing the collaborative learning game. Although majority of the participants of the experiment knew already about traffic rules and had many years of driving experience, they faced some signs of which they did not remember their meaning and had to ask from their team members. For instance, the comparison between the answers of pretest and posttest shows that four players out of six learned about the traffic rules and the traffic signs indications. Two players learned that the speed limit inside the city is 50 km/h while they answered wrongly in the pretest. Additionally, two players learned about the meaning of the priority sign. The experiment shows that the learning tasks are more challenging for those with no driving license.

To sum up, the users have found the game relatively helpful in learning the traffic rules and driving. The results of the pretest-posttest support the conclusion and user judgments about their learning as it is visible that users learn a traffic rule and they answer correctly to the posttest questions. The results from the observation verify the questionnaire's data. It is observed that the participants ask questions about the traffic rules and road signs from each other, also it is perceived that the form of the game and strategy engaged the users a lot in the game to think, discuss and solve the problem. This result shows that the game was challenging enough for users to lead to a strong collaboration.

Adopting mixed reality for the serious game design was quite fitting the learning objectives. Players were attracted and engaged fully in the game by manipulation of physical signs and cars. The territoriality of tabletops was suitable for the users as each user was responsible for a side of tabletops buttons or signs. By setting strategies and reflecting on opponent's actions, players have a sense of autonomy as well. During the experiment, it is observed that the rules should be simplified for users in order to feel more comfortable with the game rules. Some of the game rules and interface design changed during the experiment to improve the game flow.

V. Conclusion and Perspectives

The results from this study show that the Wizard of Oz methodology is an effective method to evaluate collaborative learning level of the serious game design. The data collected from observation and questionnaire illustrate a high level of collaboration among the team members; and a pretest-posttest questionnaire shows that the game facilitates learning of traffic rules. The observation of how players interact and collaborate together to reach the goal justifies the Wizard of Oz methodology. Although the game is experimented in paper prototype and performing the actions by wizards made the game longer, the game was very attractive for the players and quite dynamic.

This research is done to introduce a new collaborative learning system in serious game design. Adopting tabletops as an opportunity for learning traffic rules collaboratively can be considered by driving schools. Also primary schools can use a very simple version to teach children the safety traffic regulations. The suggestion for future research is to implement in the tabletop design and examine the effect of computer to synchronization of actions.

The significance of this study is to present a collaborative learning design for learning traffic rules. Additionally, it offers a new application of mixed reality in serious games over tabletops. The serious game design is proven to have a high level of collaborative learning; and the scenario offers an attractive turn-based game which requires strategic problem solving.

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