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Evaluation of the Usability of DEDOS-Editor

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Abstract

This paper discusses the results of a study on the usability of DEDOS-Editor, a tool created by the Universidad Rey Juan Carlos (URJC) and Universidad Autónoma de Madrid (UAM). The first version of this tool was funded by Down Syndrome Foundation from Madrid.

DEDOS-Editor is an educational tool that teachers utilize to create activities for students. The activities are meant to be collaborative, and presented on a touchscreen (ideally a touchscreen table). The goal of the study was to evaluate whether a user can easily create collaborative activities using DEDOS-Editor. The testing, which was comprised of 23 students studying either primary education or pre-elementary education, at URJC, required the participants to create activities using DEDOS-Editor. Prior to starting, the participants were thoroughly taught how DEDOS-Editor works, and then were asked to re-create seven activities, which they were shown from the students' view. This allowed us to check whether, if given the students' view of the activity, it would be easy or not for teachers to design these collaborative activities and to distinguish between individual and common elements. Their actions were observed and recorded, and at the end of the session, each completed a post-testing questionnaire. From this data, we have discerned that there are four potential issues that impede upon the usability of DEDOS-Editor. These issues are: the misuse of images cards; the understanding of the pin function; the understanding of creating global functionality; and confusion about the zones. The details and results of the study are presented in the following document.

Acknowledgements

I'd like to thank Estefanía Martin, my advisor, without whom this thesis would never have been finished. I'd also like to say thank you to David Roldán for his help during the testing observations.

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Table of Contents

List of figures

List of tables

1. Introduction

This paper focuses on a usability study conducted on DEDOS-Editor, an educational tool that employs touchscreen table-top technology in an educational setting. In order to offer a useful tool to educators, we wanted to measure its current degree of usability so we can improve the tool in future iterations. Our primary research question was whether DEDOS-Editor complies with common usability standards, and, subsequently, if it does not, how can we improve it? The limitations include a technical error present in the tool, and the work experience of our participants, which could potentially skew their views on education.

1.1 Motivation

New educational technologies are abundant, and in a very saturated market (Nagel, 2011), it is critical that the latest technology introduced to the public offers something unique and individual to educators. Even more important than the uniqueness of a product is its usability. If the technology is innovative but very difficult for users to understand or make useful, the technology will not enjoy the maximum success possible. Usability, according to Nielsen encompasses five key components: learnability, efficiency, memorability, errors, and satisfaction (Nielsen, 2012). Nielsen defines these five factors as such:

Learnability: How easy is it for users to accomplish basic tasks the first time they encounter the design?

Efficiency: Once users have learned the design, how quickly can they perform tasks?

Memorability: When users return to the design after a period of not using it, how easily can they reestablish proficiency?

Errors: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?

Satisfaction: How pleasant is it to use the design?

By striving to evaluate the strength of these five components in our work, we can improve upon our current model and ultimately produce a better product.

In this Master Thesis, we have conducted usability testing on the creation of activities within the software application of DEDOS-Editor. DEDOS, created by members of the "*Ambient Intelligent Laboratory*" (AmiLab, Universidad Autónoma de Madrid) and "*Laboratory of Information Technologies in Education*" (LITE, Universidad Rey Juan Carlos), consists of two tools: one intended for teachers' use and activity creation, which is DEDOS-Editor; and the other is DEDOS-Player, which is the application used by students to complete the activities created with the DEDOS-Editor. DEDOS is an application that can be used on PCs, Smartboards, and touch-screen tables, specifically for learners with mental or physical handicaps, though all young learns can benefit from its use. Its aim is to reinforce and support the cognitive and social capacities of its users through collaborative activities. Collaborative activities are found to provide great opportunities to learners, with participants being more likely to change roles during the activity, to investigate more ideas, gain awareness and feel more comfortable in the social environment of the activity (Rogers, 2004).

This project focuses on the evaluation of the usability of DEDOS-Editor for educators who create activities for their students with DEDOS. According to Proctor and Marks, teachers recognize computer-based games and activities as an excellent tool to achieve pedagogical success; however, they are less likely to employ computer-based games if the games are difficult to use (Proctor and Marks, 2013). Therefore, the ease of creation of activities is imperative for DEDOS to be successful among educators, and as such, the usability of DEDOS-Editor for educators is extremely important in our research.

1.2 Objective

The objective of this project is to evaluate the usability of DEDOS-Editor tool through usability testing. To achieve this goal, we have planned and organized a guided testing, wherein teachers (or future teachers) are presented with the functionality of DEDOS-Editor, and then given predetermined tasks to complete, which are to create activities most commonly requested by teachers. These tasks pertain to the creation of activities using DEDOS-Editor. Previous research on the usability of DEDOS-Editor has been done be David Roldán (Roldán, 2012); his focus as on how easily one can learn to use DEDOS-Editor and its "*guessability*" factor, which is how a first time user approaches the system, and whether he can successfully create activities without prior knowledge. The design of collaborative activities, wherein the teacher creates an activity for one student only, and then the platform

adapts the activity to be used by any number of students who interact with the tool is not a trivial task. Our research is to present to the study participants previously made activities presented via DEDOS-Player to measure their ability to recognize the common and individual elements in the work area of the activity. Additionally, we wanted to see what difficulties arise during activity creation   with the goal of improving the tool. While Roldan's work and ours have very different aims, our work should be seen as a complement to his.

The research questions of this Master thesis are the following:

1. Does DEDOS-Editor satisfy the five key components as outlined by Nielsen?
2. Where does the tool fall short in providing a quality user experience?
3. What changes can be made to improve DEDOS-Editor?

1.3. Document structure

 The structure of this document is the following:

- **Chapter 1. Introduction.** Current chapter that contains a short description of the problem, the goal and the research questions of this work.
- **Chapter 2. Background theory.** A literature review that focuses on: e-learning and gamification; students and collaborative learning; teachers and collaborative learning via touchscreen tables; and usability techniques.
- **Chapter 3. Description of DEDOS-Editor.** This section explains DEDOS-Editor's interface, its functionality, and the various types of activities that can be created. Within the information about each activity, there is also a description of how to create the activity.
- **Chapter 4. Methods and implementation.** This part of the document provides a summary of the general approach, which includes a pre-questionnaire given to a wider population; a summary of the activities presented to study participants; an explanation of the test's design; details about the lab where the study was conducted and participant population; and information on the evaluation methods.
- **Chapter 5. Evaluation.** Here, we provide the results of the testing through both quantitative and qualitative data.

- ▪ **Chapter 6. Conclusions and future work.** This section includes limitations that we faced during the study; answers to our research questions and future research possibilities.

2. Background theory

An extensive review of literature was performed on various subjects that pertain to our research. Our objective was to understand the current challenges and difficulties within evaluating the usability of an educational software application that covers a range of areas. To understand how to best evaluate DEDOS-Editor, it is necessary to research the various factors that DEDOS-Editor involves. A theme in our literature review is that of the importance of usability in educational tools; the usability affects all aspects of the success of the tool.

DEDOS-Editor and DEDOS-Player intended use is for educational purposes, and thus the fields of e-learning and gamification were researched in order to understand the purpose of DEDOS in a global sense. Research on the role of teachers in the success or failure of an educational tool was conducted in order to understand how to present teachers with our study. Collaborative learning is also an important aspect of DEDOS, as studies show the numerous educational and social benefits that students experience in a collaborative learning setting.

Since our project is that of a usability study, the crux of our literature review is focused on performing usability evaluations: best practices, technology-specific evaluations, gathering data from users and the type of questions that must be asked receive valuable user data.

2.1 E-learning and gamification

Although our project was focused on the experience teachers who would implement DEDOS in a physical classroom, given the nature of the tool, we also researched the different aspects that e-learning encompasses, and the challenges that arise when evaluating the usability of e-learning applications. E-learning has been identified as a pedagogical option that enables people to keep up with the changes in the world; however, most e-learning programs suffer from an elevated drop-out rate, usually due to lack of motivation for users (Zaharias and Poylymenakou, 2009). Another factor in the drop-out rate is the poor design of the programs, which could be mitigated by a more specific method of usability testing. Zaharias and Poylymenakou have developed a questionnaire that responds to the needs of a user in a learning context (their research is also mentioned in section 2.4 of this document).

Since DEDOS (comprised of both DEDOS-Editor and DEDOS-Player) is desktop tool that is used to teach in physical classes (as opposed to distance, on-line learning), the risks of "drop out" are nonexistent. DEDOS is intended for use within a classroom, under the supervision of a teacher. Despite its intended use, the problem of disinterest of users is still very important to the overall success of the tool, even though there is little to no risk of "drop out". The importance of user interest, and its relation to the process of learning and the effectiveness of learning has been examined through quantitative and qualitative research by Haverila (Haverila, 2009), and with these factors in mind, we set upon evaluating the DEDOS application. We used note-taking and observation, participants' comments and a post-testing questionnaire to evaluate the user interest and enjoyment of DEDOS-Editor.

Users of an educational, game-based technology have different needs than those using a task-based technology (Moreno-Ger, 2012). Games are an engaging way to present challenges and demand exploratory thinking and experimentation from learners. Just as e-learning tools need to be evaluated in a specific way, tools that employ gamification also have their own requirements.

2.2 Students and Collaborative Learning

DEDOS project tools (Editor and Player) allow the creation of activities for students that can be completed either individually or in a group, collaborative setting. Our definition of "collaborative learning" is learning in a situation in which two or more people learn or attempt to learn something together (Dillenbourg, 1999) and that this situation should be a reciprocal, coordinated interaction in which ideas and perspectives are explored and exchanged (Goos et al., 2002).

As DEDOS activities are intended for use on a touchscreen table or other large screen (although activities can be completed on Smartboards or individually with a PC), group use is expected to be the most common type, and for good reason: studies have found that there are outstanding benefits to learners working in a collaborative setting, as opposed to working individually (Schneider et al, 2010).

Various studies have investigated the benefits that learners reap when in a collaborative setting, and further advances in technology facilitate collaborative learning in news ways. Mavrou et al.'s study on collaborative learning in a computer-based setting mixed students of

different abilities (students with and without disabilities) and found that the computer helped to mediate both types of students' helping behaviors, motivation, self-confidence, peer acceptance, affection, and social-emotional status. Additionally, students interacted in physical and intellectual ways with the help of the computer, and as the computer can provide different activities and tasks, interactions of different types were encouraged (Mavrou et al, 2009). Laal and Ghodsi's research on collaborative learning affirms the idea that, in comparison with individual learning, collaborative learning, "*typically results in higher achievement and greater productivity, more caring, supportive, and committed relationships; and greater psychological health, social competence, and self-esteem*" (Laal and Ghodsi, 2012). Schneider et al. have found that when using a touch screen in an educational context for collaborative projects, students are more likely to work in a more equitable fashion (there is no one person "in charge" of the mouse (Schneider et al., 2010); thus, students when students work together in a collaborative setting, there is more likelihood that the work is more fairly divided. Yet another benefit is that research shows that students enjoy collaborative learning through technology, making the learning process more fun (Africano et al., 2004). The DEDOS tool aims to make the most of these numerous benefits, and to provide learners with a supportive, enjoyable, and productive experience. To assure that DEDOS-Editor fosters such a goal, the usability of the tool must be analyzed and must lend to creating an enjoyable collaborative experience for all users.

2.3 Teachers and Collaborative Learning with Touchscreen Tables

It is important to understand teachers' acceptance, interest and prioritization in using a tool like DEDOS, as well as any aspects of educational technology that prove to be from a pedagogical standpoint. Jen-Hwa Hu et al. examines a Technology Acceptance Model (TAM) specifically focused on the needs and interests of teachers (Hu et al., 2003). It demonstrates that one of the most important factors in teachers' acceptance of a new technology is the perceived usefulness. The success of an educational platform depends heavily on its being embraced by educators.

One huge deterrent for educators to adopt a new classroom technology is the matter of time. Karasavvidis discusses the challenges that arise for teachers in regard to time (Karasavvidis, 2009). One concern is that the teachers must learn how to use the tool, and thus need time to

understand the technology. This is an investment in resources and effort for them, as Cuban et al. explain (Cuban et al., 2001, p. 828):

> "*Teachers told us that they did not have enough time to incorporate computers into their daily teaching. They would need hours to preview web sites; hours to locate the photos they required for the multimedia project they assigned to students; hours to scan those photos into the computers; and hours to take district and corporate courses to upgrade their skills...where, they asked, would the additional time come from?*".

This issue was important in our research. We were very concerned with the time that the activity creation would take, and how long it would take for the users to adequately adopt the technology by learning how to use it without outside support.

Research shows that concerns over curriculum also dissuade teachers from implementing Information and Communication Technologies (ICT) from their lessons. The need to cover a tightly scheduled curriculum does not allow sufficient leeway for the teachers to use all ICT; the technology they use needs to adaptable to their needs and to the lessons they must give (Karasavvidis, 2009). DEDOS aims to do this through its freedom of creation; any user can create an activity with his own resources, tailoring the lesson to the needs and interests of his students. This, however, directly relates back to the previous issue of time; if a teacher has no time to learn how to use the platform, and it is not easy to learn in a timely fashion, its adaptability is secondary. For this reason, in our research we focused on measuring how learnable DEDOS is.

Al Agha et al. investigated the relationship between teachers and touchscreen technology and its importance in the classroom (Al Agha, 2010). The integration of touchscreen technology cannot replace a teacher, especially at the elementary level, as the teacher is the main orchestrator of the educational process. The importance of creating an educational tool that is easy for teachers to use and create activities goes hand in hand with the importance of the usability of said tool.

Teachers' role in evaluating educational tools is extremely important. Many usability evaluations call upon experts who can use their knowledge to appraise the technology. In the case of DEDOS, a Structured Expert Evaluation Method (SEEM) should be conducted by

educators, since their pedagogical backgrounds make them experts in education, and thus, their opinions will yield important data (Bekker et al., 2008). Teachers' expertise can mitigate possible problems within DEDOS; their experience with elementary-age students gives them a perspective that the developers of DEDOS may not have.

Kharrufa et al.'s research hinged on the hypothesis that, "*if well utilized, the digital table-top's unique affordances would allow for the creation of collaborative learning tools that were better than traditional paper - or computer-based tools*". Their paper concludes that the success of collaborative learning on a touchscreen depends greatly on how well the educational tool is designed (Kharrufa et al., 2010).

2.4 Usability Evaluation

Evaluating DEDOS's usability is the objective of our research, and as such, different methodologies of usability evaluations have been thoroughly reviewed. The research has focused on evaluating learning tools, games and the creation of collaborative activities for touchscreen technology.

The usability of technology makes or breaks its success, and as such, is crucial. A poorly designed interface makes students spend more time in learning how the interface works rather than in mastering the material, causing the technology to become a barrier against effective learning (Ardito et al., 2004). Clearly our intent in this project is to provide a usable technology to teachers that will promote the creation of collaborative activities, and to students that will assist in their learning experience rather than hinder it. To understand the factors involved in DEDOS' usability, various sources and techniques were employed.

Traditional usability measurements were used as a backbone to the investigation (Nielsen, 2012) though they can fall short when it comes to evaluating educational tools (Zaharias and Poylymenakou, 2009). A need for a focused questionnaire arises, since other standard usability questionnaires do not address the specific needs of an educational tool. Through data collected from a concise questionnaire, it is easier to identify the structure of relationships of problems within the system. Research also shows that a combination of methodologies yields the most conclusive results (Thyvalikakath, 2009). The role of the notetaker who observes the testing and the users is an important part of the assessment of

usability, and deciding which metrics are important to keep track of will help the research be more conclusive and applicable (Davis, 2012).

One process we were inspired by was the Structured Expert Evaluation Method (SEEM), which consists of two phases: the execution phase, and the evaluation phase. In the case of educational games, experts determine if the goal of game can be perceived and understood (Bekker et al., 2008). In evaluating DEDOS, we decided to take a similar approach. Although the research conducted by Ardito et al. was strictly focused on e-learning rather than a generic learning platform (Ardito et al., 2004), their research found that when conducting usability studies, the following criteria must be focused on:

A. *The analysis of learning needs: in designing the courseware, has a detailed analysis of the learning needs been performed?*
B. *Definition of learning goals: are the learning goals well-organized in terms of cognitive and metacognitive abilities that the learners have to acquire?*

The role of usability in the effectiveness of an educational tool is extremely critical. One consequence of poor user experience due to limited usability is that the educational factors of an application decrease if the user feels lost within the system due to the hypertexts present (Parlengeli et al., 1999). Another cause for failure in educational technologies is usability issues that make the positive aspects of learning seem less effective (Minovic et al., 2008). If a user is able to learn from a tool but experiences high levels of frustration with its interface, for example, the perception of what he or she has learned is lowered. Though the usability of technology is often overlooked or seen as the lowest priority, this is a damaging standpoint that obviously affects users. Due to these shortcomings, the e-learning world faces an "interface issue", which, through usability testing could easily be avoided, as interface limitations can be identified easily and quickly through testing, allowing for improvements to the look and feel of the application's interface (Granic, 2008).

3. Description of DEDOS-Editor

After reviewing related projects and papers related to this Master Thesis, this section describes DEDOS-Editor, which is used by educators to create individual and collaborative activities. As explained in the following section, though the usability evaluation covers the two tools (DEDOS-Editor and DEDOS-Player), the majority of the study is focused on DEDOS-Editor, since the objective of this project is for the users to create collaborative activities. With this in mind, this chapter explains the DEDOS-Editor while the following describes the goal of DEDOS-Player within this study.

3.1 Description of DEDOS-Editor's interface

The authoring tool DEDOS–Editor has been developed to allow teachers to create card based single and multiple selection activities in an easy way. It can also allow the update of previous educational projects. The authoring is based on using cards with text or images. To increase the potential of the tool, cards can be grouped in areas. There are two possible areas: the board and the student area. All students share cards in board areas, while those in student areas are specific to each student and, consequently, automatically replicated so that every student at the table has their own. Activities are then grouped into a project to create a coherent learning set that can be later used in the classroom.

When the program is first opened, the user sees what is displayed in Figure 1. The interface of DEDOS-Editor consists of four main areas, which are labeled in Figure 1:

- **Area 1** is the "preview activity" area, where the user can see all the activities she has created in the current project. The "add" button is located here, allowing users to add another activity to the educational project. Users can also include other activities using the menu of the tool ("Activity – Add").
- **Area 2** is the toolbar. It contains four distinct sections, shown in Figure 3, and its tools are used to include areas, cards and objectives in activities.
- **Area 3** is the editing area. Users drag and drop items from area 2 to area 3 in order to create the activities. The recycling bin is part of this area, here users drag and drop items they do not wish to have in the editing area.
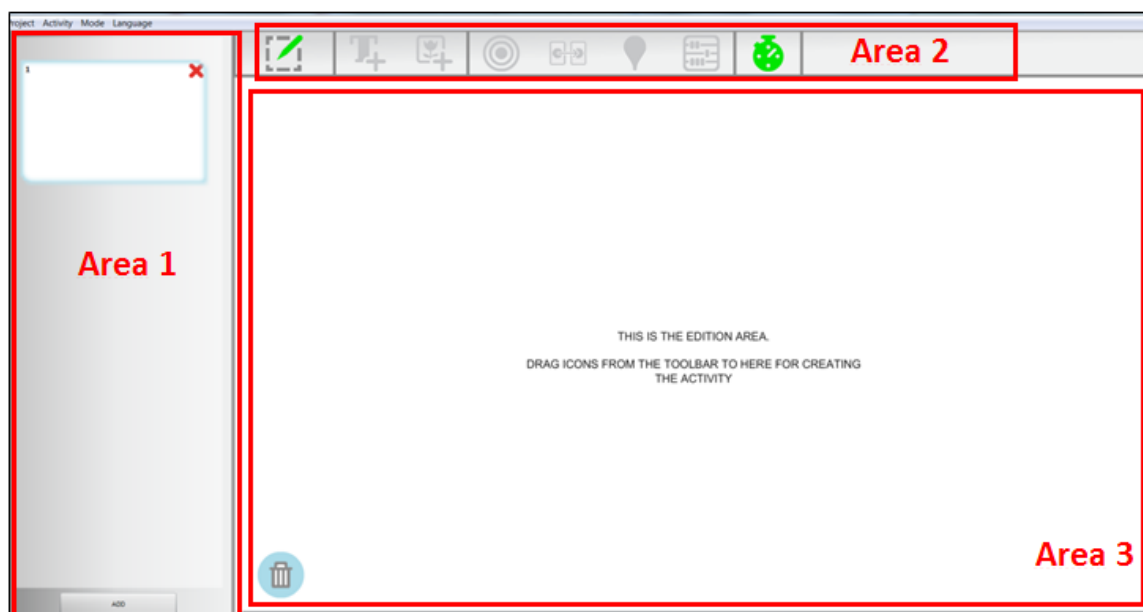
Figure 1. The four areas of DEDOS-Editor

The "*preview activity*" area consists of two parts: a preview thumbnail of all the activities created within the same learning project and the add button used to include a new activity to the current set of activities. Furthermore, if the teacher wants to include a new activity, she can also add it using the upper menu of this tool. The menu also allows users to choose the mode (basic or advanced) and the language (Spanish or English).

The toolbar area, located on top of the editing area, is divided into four sections according to each section's functionality. Figure 2 represents the toolbar area in detail, with red, numbered labels for each section, which are explained below:

1. The first tool is used to create a zone. A zone is a group of elements that allows organizing them. To make activities the user needs to create a zone by dragging and dropping the zone card onto the editing area. This tool is also shown in Figure 4 and Figure 5 in more detail, with an explanation of its elements.

2. The second tool has the main building elements of this authoring tool: text and image cards. They can be grouped in zone areas. On the one hand, the text card provides to user the inclusion of text in an activity. She needs to drag and drop this card onto a zone in order to add text. On the other hand, the image card that can be dragged and dropped onto a zone in order to add a picture. The editing process for both cards and the process to upload an image in an image card are explained later in this document.

Figure 2. Toolbar area in detail.

3. The third tool is the interaction toolbar, which defines the type of activities that can be included in the educational project. It has four separate objectives, each of which corresponds with an activity.

- The first button, a green target, can be dragged and dropped in order to make an object selectable. This target allows indicating that the object selectable is the correct answer in the activity. In this case, the student must to select the object selectable for an activity. It is possible to define different selectable objects in the same activity.

- The second button is the matching functionality. This is to create activities which pair two objects together. When a matching relationship is established between two objects, the user sees an arrow that indicates this type of relationship between the objects. The matching can be established between cards or, a card and the objects in a zone.

- The third button is the paths button. It is used to create pathways that the child must connect, similar to a connect-the-dots activity. This target has not been used in this research work.

- The fourth button is the counter button, which can be used to create mathematical functionality in activities. It must be used in conjunction with other functionality, such as the matching functionality.

4. The last tool is the timer, which is used to create timed activities. If a timer is included in the activity, the designer must specify the maximum preforming time in seconds for this activity.

DEDOS-Editor by default makes an activity as if it were intended for a single student. The tool can be used for individual devices, or in devices that are more appropriate for group settings. In this case, there will be more than one student interacting with the device and thus the elements will be grouped for individual and collaborative use. The game zone will be placed in the middle of the device to promote interaction between all the students who are collaborating with this device. On the other hand, player zones will be replicated as students will be interacting with them. To make activities you need to create a zone, which can either

be a player zone (shown in Figure 3) that is visible to individual or groups of players or game zone (shown in Figure 4), which is where the games' actions take place. The player zone is the non-collaborative element of the game and is only shown to individual players, while the game zone is the collaborative element, which all game players can see. When the teacher wants to add a zone, she simply clicks on the figurehead placed in the upper left-hand corner of the zone card once the card is dragged and dropped into the editing area. By default, the zone is in player mode. When students will interact with DEDOS-Player to do the educational activity, the game zone will be placed in the middle of the device to promote the interaction of all the students who are collaborating on the device. On the other hand, player zones will be replicated as students will be interacting with.
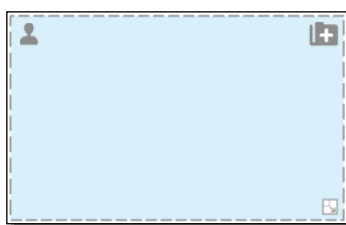
Figure 3. The Player Zone card.
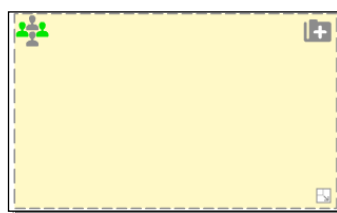
Figure 4. The Game Zone card.

Both the text and image cards share three characteristics: anchoring, advanced options, and resizing. In the top left corner, there is a pushpin, shown in Figure 5. If you push the pin in, you anchor the cards position, making it unmovable unless you select the pin again. This behavior is present in both DEDOS-Editor and DEDOS-Player. The teacher specifies that this card cannot be movable for the students. In the bottom left corner, shown in Figure 6, there is a cog, which when selected, brings users to the advanced options. The advanced options available (shown in Figure 7) allow the user to make the text or image card selectable, turnable, and/or resizable by the students. Additionally, this is the function that a user would employ in order to give feedback to a student, or to provide the numerical value of the card for mathematics activities. Finally, there is an arrow in the bottom right corner (shown in Figure 8). This arrow is used to change the size of the object to the users' needs. It is also featured in the zones. To adjust the size, simply drag the arrow either away (enlarging the object) or back in toward the object (shrinking it).

Figure 5. Anchoring a text or image card.

Figure 6. Advanced options cog.
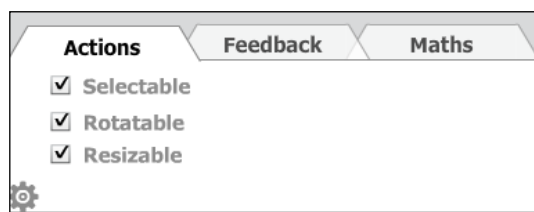
Figure 7. Advanced options.

Figure 8. Resizing arrow.

Finally, the folder icon, located in the upper-right corner of the image card or a zone, is the icon we click in order to select an image from our files (see Figure 9). After selecting the folder icon, a dialog box opens, allowing the user to select the desired files. If you are inserting an image in a zone, it will appear as the background of it. However, if you are inserting images into a card, they appear as the main element of the card. In the latter case, the teacher may decide to include more than one image on a card. On each occasion, DEDOS-Player shows different image by randomly selecting one set provided by the teacher. This happens for two reasons: to prevent students from memorizing them and so that when students are doing activities in a collaborative setting, each student has a different image. For example, if we had a card with images displaying several types of containers need to be recycled, one student's card could display a milk carton, another's would have a soda can and the third student's card could show a plastic bag.

Figure 9. Add image from file to Image Card option.

3.2 DEDOS-Editor's functionality

DEDOS-Editor is one of two tools involved in creating and employing DEDOS activities. The editor, intended for educators, is where activities are created for the end-user (students). Educators use the editor solely for creation of activities; after being created, these activities

can be completed through the DEDOS-Player. There are three main types of activities that we have researched for this Master Thesis; they are described below.

3.2.1 Creation of a selection activity

A selection activity is an activity that requires the end-user to select the correct answer to a question/problem by simply selecting it (tapping on the screen). In order to create a selection activity, we first create at least two zones. The example of Figure 10 presents an activity with two zones. It is not always necessary to create two; it depends on the type of activity you want to make. It is possible to create just one zone. In this case, first, add two zones to the editor area, and make one for the game and one for the players.
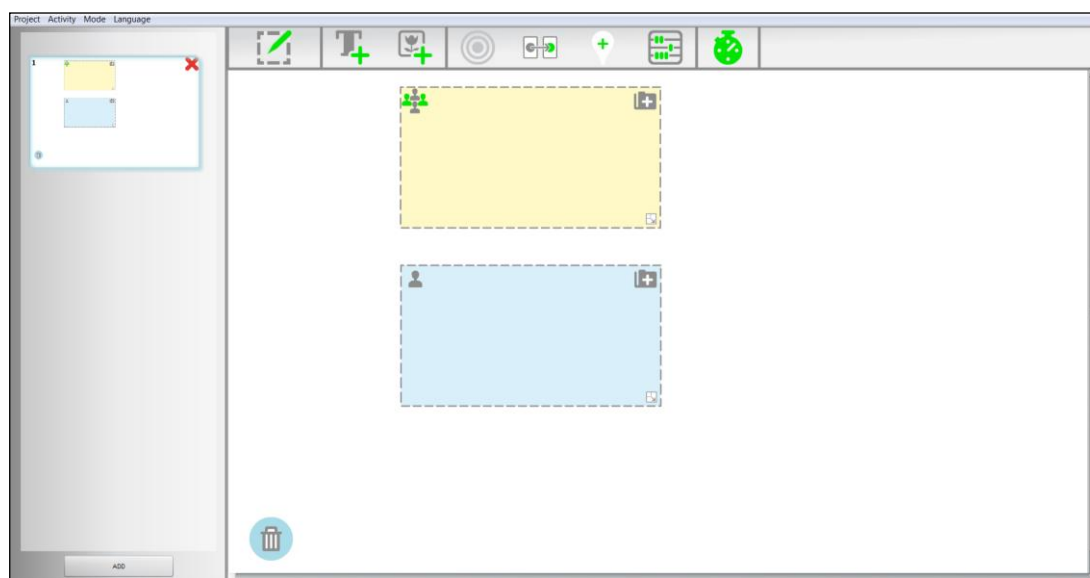
Figure 10. Two Zones in the Editing Area.

Then, add text to the game zone proposing a question to be answered by the players (Figure 11). In this example, we include the activity question in the collaborative zone and the possible answers in the individual zones.

Next, we use the image card to add images of possible answers to the question. More than one image can be place within the same card; they will be randomly dispersed to different players. However to create different possible answers, it is necessary to drag and drop different image cards to the player zone and load them with distinct images. In Figure 12, we can see the images that will appear to the individual players as possible answers.
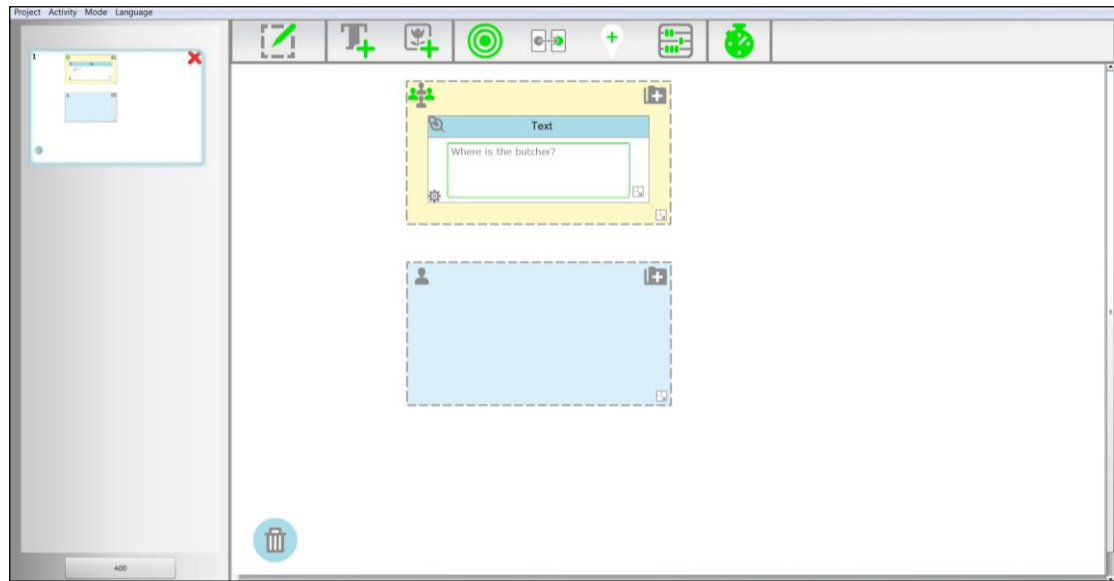
Figure 11. Textbox added to the Games Zone.
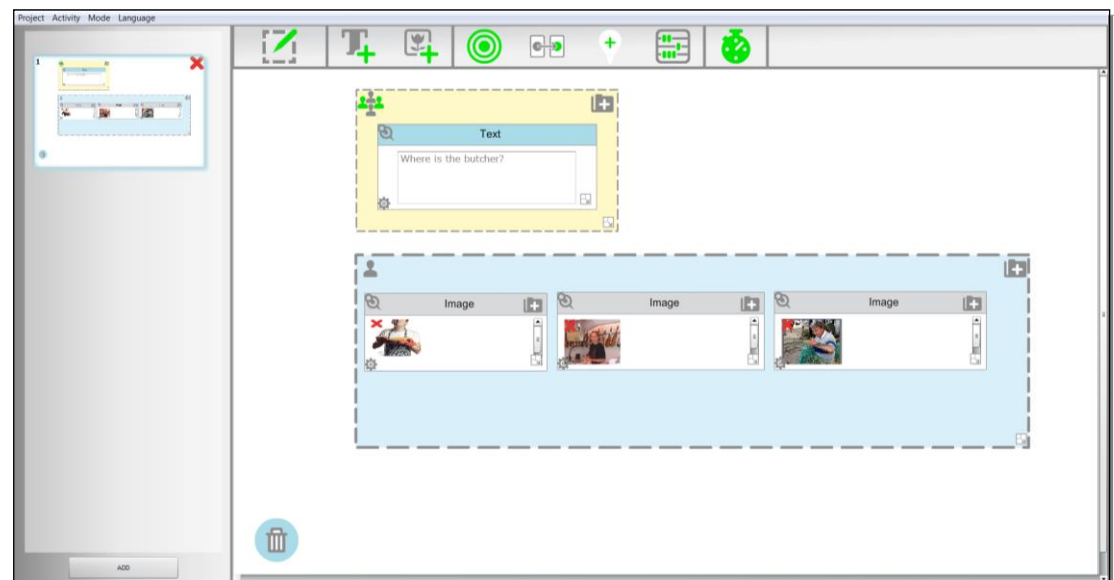
Figure 12. Images added to the Players Zone.

Lastly, we add the functionality to make the activity interactive. To do this, select the green target and drop it onto the correct image card (shown in Figure 13). The green target is the selection tool, which will allow the card to be the only correct answer to solve the activity correctly.

Since this is a selection activity, we do not want the cards to be movable to the students. In order to do that, we click the pushpin, pushing them in and thus making the cards with pushed in pins (in this case, all of them) static. Figure 14 demonstrates the selected answer card with the pushpin pushed in. Once the pin is pushed, the user cannot move this card from the site established by the teacher.
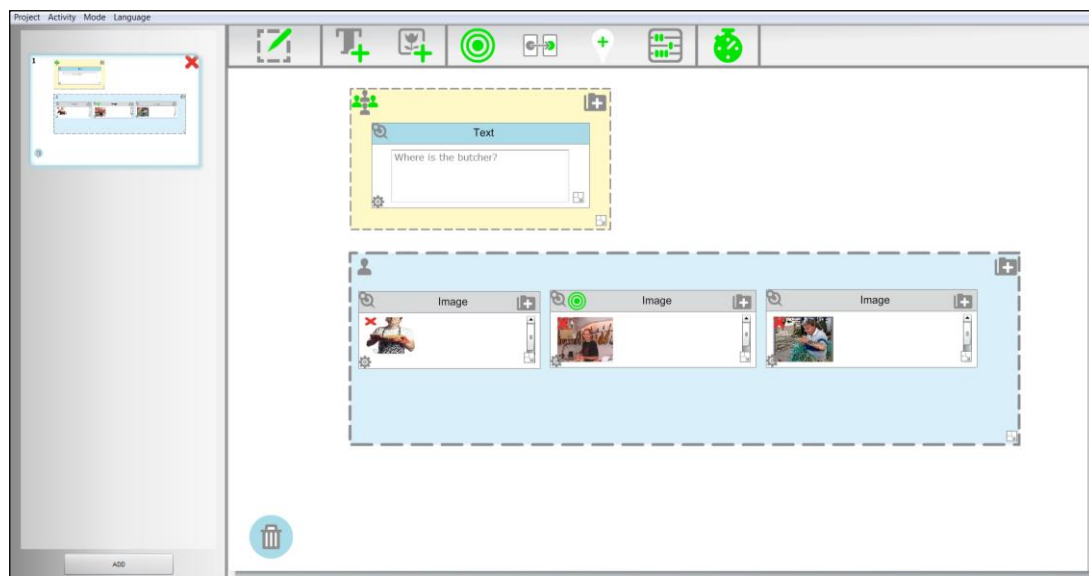
Figure 13. Selection tool added to the Players Zone.

Figure 14. Pushpin activated.

3.2.2 Creation of a matching activity

Matching activities call for the end-user to physically move the correct item toward the answer zone that it corresponds with. The matching activity, unlike a selection activity, requires that the cards that are selectable are mobile. To create a matching activity, we first create two zones for example. Then, add two zones to the editor area, and make one for the game and one for the players. After, just as in the selection activity, add text to the game zone proposing a question to be answered by the players. Next, we use the image card to add images of possible answers to the question. More than one image can be place within the same card; they will be randomly dispersed to different players. However to create different possible answers, it is necessary to drag and drop different image cards to the player zone and load them with distinct images. Lastly, we add the functionality to make the activity interactive. To do this, select the green and gray arrow and drop it onto the correct image card (shown in Figure 15). The arrow is the matching tool, which will allow the card to be matched with the designated answer(s). With matching activities, we do not activate the

pushpin (anchoring) option on the cards offered to the students, since they will drag and drop the image card(s) to the correct destination and thus need for the card to be movable.
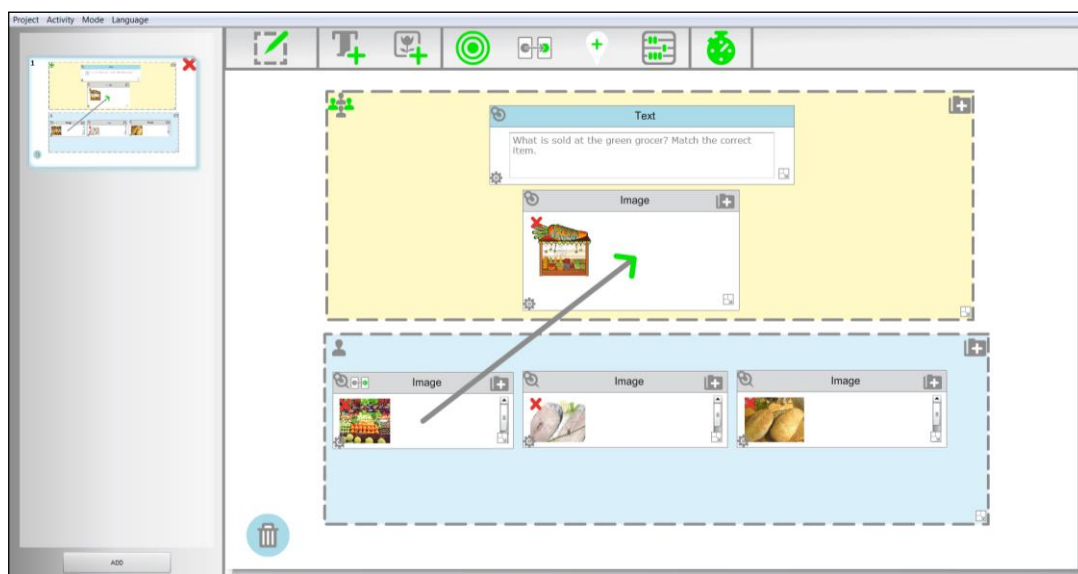
Figure 15. Example of matching activity.

3.2.3 Creation of a mathematical activity

Using the card counter in conjunction with matching activities, we can create mathematical activities. To do so, we first need to add two zones to the editor area, and make one for the game and one for the players. After, provide a question to the students by adding text to the collaborative zone. Next, we use the image card to add images of possible answers to the question. Again, multiple images can be placed onto the same card. Once you have created the image cards, you must give the appropriate numerical value to them. For example, we write the activity as, "You are having a party and need to buy bread. Put 3 baguettes in the basket". With each picture of a baguette, we assign the correct numerical value by clicking the advanced options widget, selecting the math tab and adding the correct number to each image (see Figure 16); this number represents the numerical value of the image displayed. By default, the value assigned to image cards is 1. If more elements are displayed in the picture, the teacher must provide the correct numerical value.
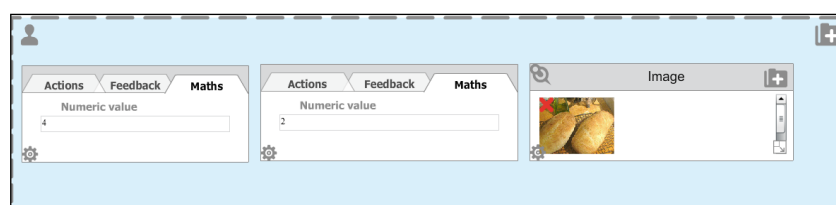
Figure 16. Adding a numeric value to an image card.

Once the appropriate numeric values have been set to the image cards, you must drag and drop the counter tool onto the question prompt (or wherever the users are expected to either drag and drop or match their answers to). By clicking on the counter tool, you can assign the appropriate numeric value (see Figure 17). This number represents the total number of elements that user must drop onto it to successfully finish the activity.
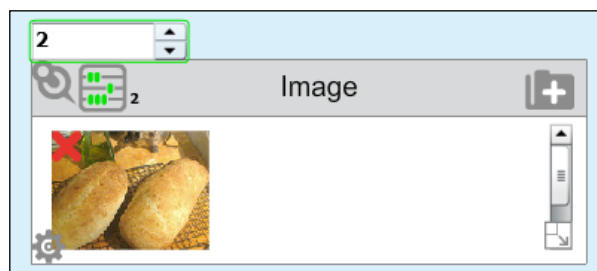
Figure 17. Using the counter tool.

Then, we add the functionality to make the activity interactive. You may choose the functionality that would appropriate according to the question you are asking: keep in account whether the image cards should be movable or not. In our example, we have made the whole player area selectable with matching, so that a combination of answers is possible (see Figure 17). This design is more flexible for the students, since it allows each student to provide a different combination of answers to finish the activity. The full example of a mathematical activity can be shown in Figure 18.
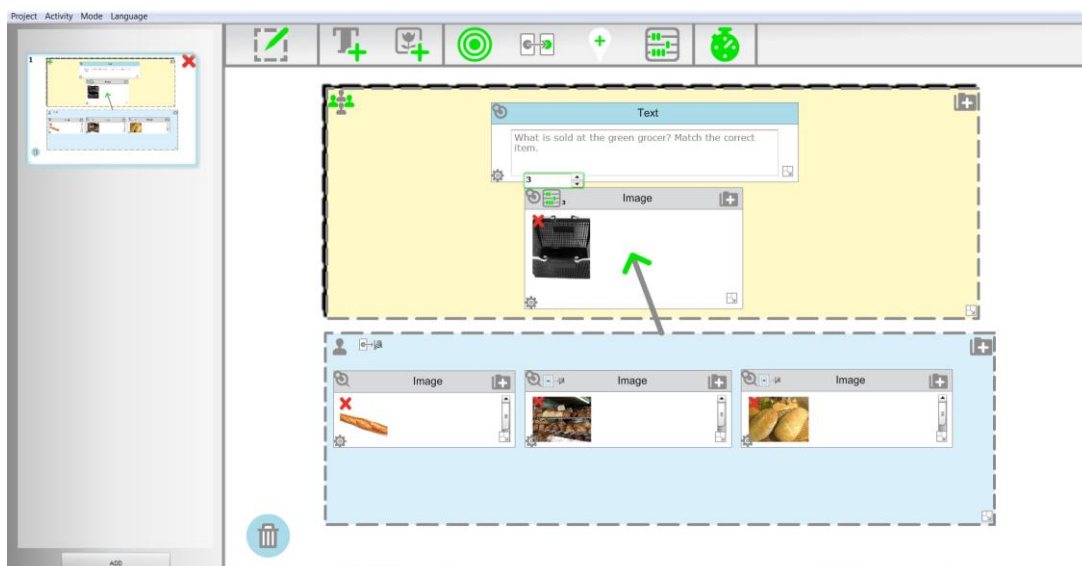
Figure 18. Matching with a whole zone selectable.

4. Methods and Implementation

Based on the background research, the implementation of a multi-step process of evaluation was created, with an emphasis on a customized evaluation questionnaire. The first step of the process was the creation and data collection of a pre-questionnaire. The responses to this were used to frame the questions in the final evaluation questionnaire. The second step was the creation of the activities that the evaluators would have to re-create; these activities needed to encompass every aspect of the DEDOS Editor that needed to be evaluated. The third part was the in-lab testing, where the evaluators attempted to re-create the previously defined activities and then, at the end of the session, responded to a questionnaire. The fourth and final part of the experiment's process was the examination and interpretation of the data. The characteristics of the pre-questionnaire, a summary of the activities that participants were requested to recreate, the test design details including logistical aspects, and the evaluation methods are presented.

4.1 The pre-questionnaire

Prior to any testing, we created a pre-questionnaire that was sent through social networks and email to people who were currently working or have worked either as English Language Assistants in Spain or as teachers in the United States. The goal of this data collection was to understand the needs and preferences of teachers and teaching assistants regarding an educational tool. With the data collected, we were able to prioritize which aspects of the user experience would be most important to the users. The full questionnaire is included in annex A of this document.

There were 11 respondents total. Their responses were anonymous. The 11 respondents were either in their first year as a teacher (0 years of prior experience) or had up to 7 years of teaching experience. Nearly half of the respondents had 2 or more years' experience (see Figure 19).

Regarding needs and preferences, the two most important aspects for the teachers are that the application would be useful in class (rated 1.55), and that the application is easy to use and create activities with (rated 2.00). Table 1 presents the results obtained to statements sorted

by the average rating of importance. The scale used is between 1 (highest priority) and 4 (lowest priority).
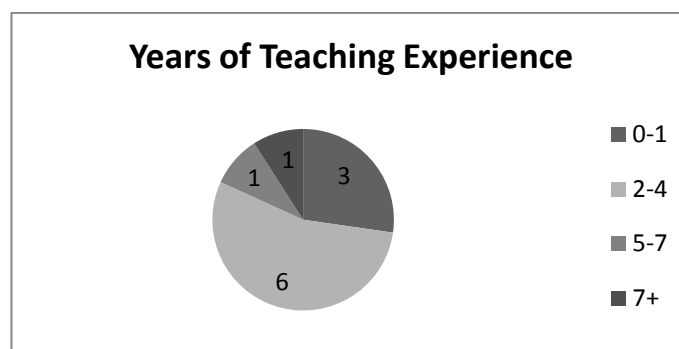
Figure 19. Pre-questionnaire: Response to the question "How many years of teaching experience do you have?"

Table 1. Rate the following statements in order of importance, 1 being the top priority and 4 being the lowest priority.

Statement	Importance
The application is useful and would help my class learn and be more productive.	1.55
The application is easy to use; the children understand how to use it and it is easy for me to create activities.	2.00
The application is easy to learn; once the students and I know how it works, we have no problems remembering how to use it.	3.36
The application is satisfying; I am happy with how it works and so are my students.	3.09

From the information in Table 2, the idea that usability and usefulness are of the utmost importance to the users is reaffirmed. The ease of use (how easy it will be to create games/activities) is the second highest rated characteristic, and, therefore the usability evaluation created for the in-lab testing must include elements about the usefulness of DEDOS. To further examine the priorities and interests of the teachers, the question "What would the most important aspect be for you as the teacher?" was posed. Table 2 shows the breakdown of responses. The most important factor for the teachers was the application's effectiveness at reinforcing ideas from the subject, underlining the importance that DEDOS must not be a source of frustration or distraction, which can occur if the user's experience is negatively impacted by shortcomings in the tool, and affecting its' overall usability.

Table 2. Rate the following statements in order of importance, 1 being the top priority and 4 being the lowest priority.

Statement	Importance
How easy it is to create games/activities	2.00
How easy it is to change the level of difficulty of activities in the game	3.55
How the application appears visually	3.55
How easy it is to remember the process of activity creation once you know how to create activities	4.36
How effective the application is at reinforcing ideas from the subject	1.55

The responses to this question showed that the evaluation of DEDOS must measure how easy it is for users to create games or activities. Ease of use is often analyzed in usability studies; in the research conducted about the usability of DEDOS, it will be a focal point. For the other questions raised, there was a tie between two aspects (ability to change level difficulty and the application's visual appearance), with a relatively high score of 3.55. This indicates that while the visual aspect of the tool and the option to change activity difficulty are not high priorities for the teachers. Additionally, and rather surprisingly, the learnability of the application (how easy it will be to remember how to create activities) has the highest score of 4.36, demonstrating that, for this group, the application's learnability has the least importance in relation to the other factors.

4.1.2 The creation of the activities

As mentioned in section 3.2, there are a variety of activities that can be created with the DEDOS-Editor. This document addresses the creation of activities using the DEDOS-Editor, and as such, the in-lab testing required a range of activities to evaluate every possible aspect of the DEDOS-Editor. The level of difficult to create the activity varies, and the order of activities was randomized to prevent the users from building on previous knowledge while they created activities.

Users had to create the following activities:

1. Simple matching activity (one correct answer): This activity required the user to create two zones (one player and one collaborative) and add the appropriate elements and functionality with one correct answer (Figure 20).
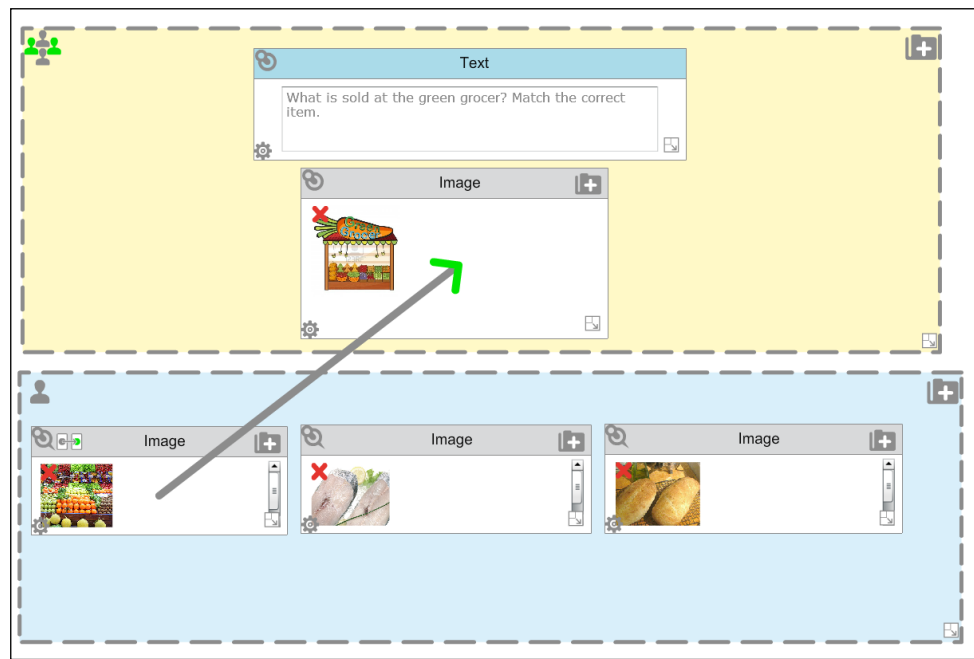
Figure 20. Matching activity, one correct answer

2. Matching activity with multiple answers required: This activity required the user to create two zones (one player and one collaborative) and add the appropriate elements and functionality with more than one correct answer (see Figure 21).
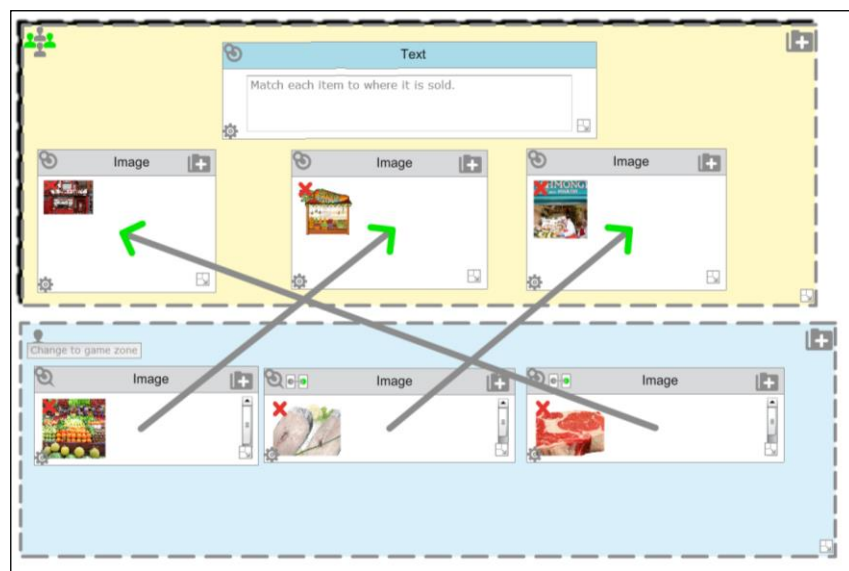
Figure 21. Matching activity, more than one correct answer.

3. Selection activity: This activity required the user to create two zones (one player and one collaborative) and add the appropriate elements and functionality with more than one correct answer (Figure 22).
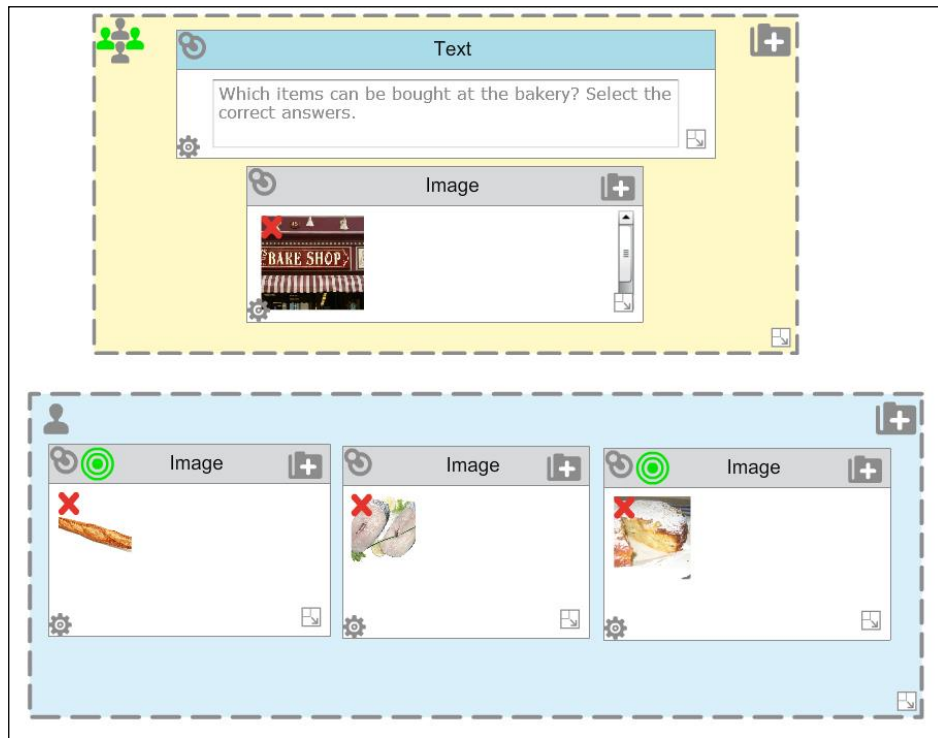
Figure 22. Selection activity

4. Selection activity with text boxes: This activity is a normal selection activity. However, the phrasing of the question and the inclusion of numbers made it appear like a math activity, challenging the users to determine what kind of functionality was necessary (Figure 23).

Figure 23. Selection activity, with text boxes

5. Math activity using the card counter function: This activity required the user to create two zones (one player and one collaborative) and add the appropriate elements and functionality, using the card counter and allowing various responses by allowing selection of any object in the player zone to be selectable (Figure 24).
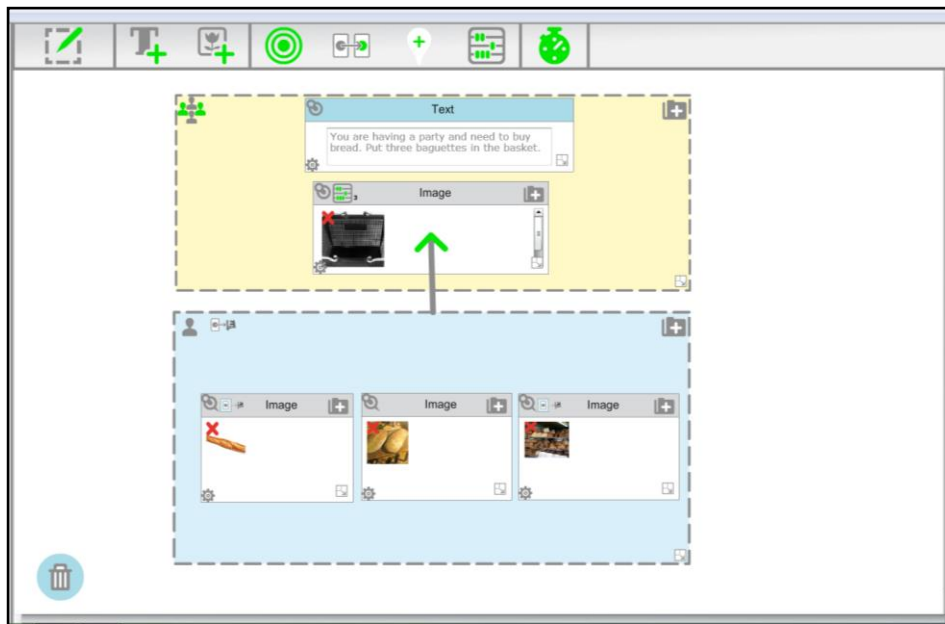
Figure 24. Math activity, using Card Counter

6. Matching activity with two answers required: This activity required the user to create two zones (one player and one collaborative) and add the appropriate elements and functionality (Figure 25).

Figure 25. Matching Activity , two answers required.

7. Matching activity with card counter and two players' zones: This is the most challenging activity, requiring the user to create one collaborative zone and two players' zones. The card counter must be used, and various answer combinations must be accepted (Figure 26).
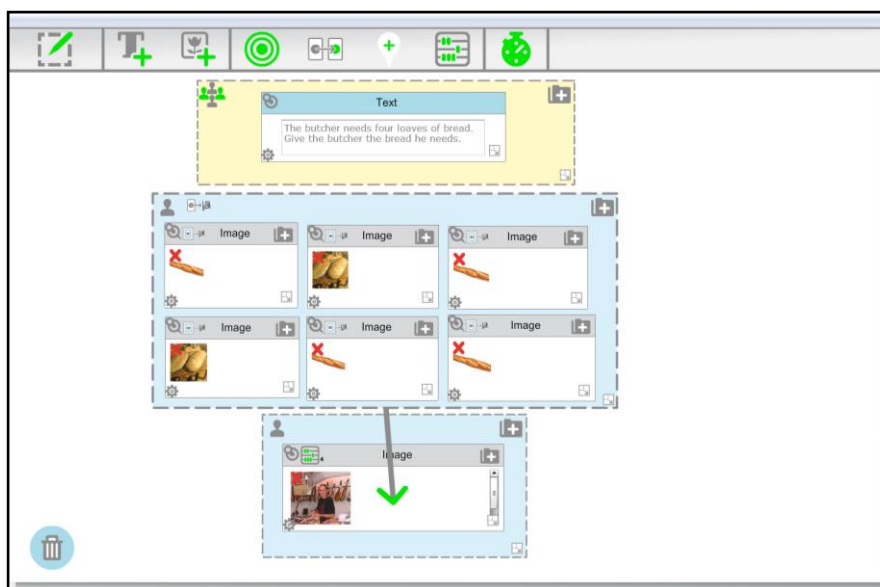
Figure 26. Matching Activity with Card Counter and two Players' Zones.

4.1.3 Test Design

The script used during the usability evaluation with participants is included in Annex B. The testing was designed to follow this order:

1. Explain to users what DEDOS is and what the objective of the testing is.

2. Explain the different parts and uses of the DEDOS-Editor.

3. Show examples of how to construct the three main activity types that we are focusing on in this study (matching, selection and math) in the DEDOS-Editor. Additionally, they are shown how students would see these activities in DEDOS-Player to understand students' tool of the students and how DEDOS-Player program, despite the fact that the design was for a single user, adapted the activity to the number of selected users who were supposedly interacting with activity. These examples help them understand the differences between common and individual elements and see the different modes of interaction depending on the type of activity created.

4. Explain to users that they will see 7 separate activities, but shown in the DEDOS-Player on the smartboard in front of them. They will have five minutes to try to re-create the activity in the DEDOS Editor. They are not prohibited from using DEDOS-Player in order to check if the activity has been correctly made.

5. Users create the activities independently, while their actions are recorded by the note-takers.

6. Users complete a post-testing questionnaire. After completing all the activities, each study participant replied to a series of questions in a questionnaire. The questionnaire (full text available in Annex A of this document) was used to assess the users' overall experiences with the DEDOS Editor, as well as to focus in on the key issues that educational tools encounter, as defined by the review of literature and the results of the pre-questionnaire.

4.1.4 User population

Testing took place over three days (Wednesday, May 8; Thursday, May 9 and Friday, May 10, 2013) and nine sessions with 23 total users. It was located at the Universidad Rey Juan Carlos, campus Vicálvaro, in Madrid, Spain.

The 23 participants in the study were all current students at the Universidad Rey Juan Carlos in their first, second, third or fourth years of a degree in either early elementary education (Educación Infantil) or general elementary education (Educación Primaria). The users had varying levels of experience in a pedagogical setting. Sixteen participants had 0-2 years of experience and the remaining seven had 3-5 years of experience. There were 2 male and 21 female participants.

4.2 Evaluation methods

The evaluation of the usability of the DEDOS Editor was based on two methods: observation of the users during the testing sessions and the users' responses to the post-testing questionnaire.

Notes were taken by two separate observers in each session. Each observer was responsible to observe and annotate the process of the users, and was responsible for observing no more than two users at a time. The observers (or note takers) all had experience or had studied the theory of usability testing. Notetakers took metrics on:

1. If an activity is successfully completed or not. If not, at what point in the process did the user fail?
2. How long the user took to complete each activity.
3. Users' attitudes and possible interactions with other users during the testing.

The results of both evaluation methods are presented in the next chapter of this document.

5. Evaluation

In this chapter, we present the findings of our testing, with both qualitative and quantitative data. The average time and rate of success for each activity is provided, as well as information about the types of errors and frequency that they occurred in each activity. Possible causes for the errors are outlined, as well as potential solutions.

5.1 Usability testing observations

In this section, the average times for users to complete the activity, the rates of success, and any pertinent comments or actions noted during the testing are included. Table 3 shows the average times and rates of success for each activity. When the user begins to interact with a new tool, he has to locate the functionalities and therefore first activities require more time. Also, another related factor is that when the number of elements included in the activity increases, the time needed to create the activity also increases. In the cases where a percentage is not given for the rate of success, it is due to the fact that time constraints prevented users from completing the activity.

One of the limitations encountered during the observations was that some participants were unable to complete the activity creation in the allotted time. In the case that users did not complete creating an activity, the amount of users who did not complete the activity is listed, and their data are not included in the rate of success column.

Activity	Average time (in minutes and seconds)	Rate of Success	Number of users who did not complete the activity
A1	3 min 55.8 seconds	100%	
A2	3 min 54.0 seconds	100%	
A3	2 min 49.8 seconds	100%	
A4	6 min 01.8 seconds	78.26%	5
A5	3 min 28.8 seconds	100%	
A6	2 min 16.2 seconds	95.65%	4
A7	5 min 43.8 seconds	100%	1

Table 3. Average time and rate of success for each activity

During the first three activities is that the average time to create their own activity decreases as expected, given the users' growing knowledge of the tool. In Activity 4, the creation time

greatly increases. This is due to the number of elements that are included in the activity are almost twice that of other activities (see Figure 23). In Activity 5, the average time drops back down, and then the average time increases gradually in the sixth and seventh activities due to the growth in the number of elements to be inserted in the activity.

Next, the main findings for each activity will be presented, identifying the most common difficulties and the problems encountered by the participants.

5.1.1 Activity 1

The average time to complete the creation of activity 1 was 3 minutes 55.8 seconds.

Since it was the first activity, it was more likely that the users had some difficulties in navigating DEDOS-Editor, a problem that, with experience using the tool, subsided. As we can see in Table 4, the placement of cards with the statement of the problem included in the collaborative area must be fixed, so students cannot move these cards in a collaborative learning environment. The most common error was that users did not pin down the items that needed to be static: three out of 23 users made this error. The specific errors made are being identified in Table 4.

Table 4. Errors encountered in Activity 1 and their frequency.

Error type	Frequency
User doesn't pin down items that need to be	13.04%
User created zones for each player	13.04%
Placement of distinct images within same card (i.e. photos of 1 loaf of bread, 2 loaves of bread, etc all in same card)	4.35%
Use of individual zone instead of a collaborative one	4.35%
Use of individual zone instead of a collaborative one	4.35%
Use of individual zone instead of a collaborative one	4.35%
User puts arrow going in the wrong direction in the functionality (connects the collaborative zone to the individual zone)	4.35%
User uses wrong functionality (selection instead of matching)	4.35%

The placement of distinct images within the same card is an error, because all images included within the same card will have the same value. For example, if one image card contains an image of a butcher and an image of a baker, and the activity asks for the student to match the baker to the bakery, both of the images would be accepted as the correct answer, since that card is marked as the correct one. This leads to confusion, and must be avoided. In the case of the arrow pointing in the wrong direction, this indicates that the participant did not

distinguish between the collaborative zone and the player's individual zone. With the case of users implementing the wrong functionality, it is highly possible that they did not read the activity's prompt and ignored the word "match"; instead of creating a matching activity, they created a selection activity.

5.1.2 Activity 2

The average time to complete the creation of activity 2 (see Figure 21) was 3 minutes, 54 seconds. The activity was completed with 100% success. The most common errors were: users placing various images within the same element when they needed to be separated (images are not related to be added in the same image card), and users pinning down elements that need to be movable. Both were made by 2 out of 23 users. The specific errors made are identified in Table 5 below.

Table 5. Errors encountered in Activity 2 and their frequency.

Error type	Frequency
Use of individual zone instead of the collaborative one	8.7%
User pinned down something that needs to be movable	8.7%
User confuses text card with image card	8.7%
Use of object cards instead of zones	8.7%
User doesn't pin down items that need to be	4.35%
User puts individual objects in the collaborative zone	4.35%
Placement of distinct images within SAME card (i.e. photos of 1 loaf of bread, 2 loaves of bread, etc all in same card)	4.35%

5.1.3 Activity 3

The average time to complete the creation of activity 3 (see Figure 22) was 2 minutes, 49.8 seconds. There were three most common errors: the users did not pin something down that should have been, the users pinned down things that needed to be movable, and the users chose the incorrect functionality to create the activity. In these three errors, two users out of 23 made mistakes. The issue of choosing the incorrect functionality is a comprehension problem (users did not understand the activity that they needed to make and the necessary functionality in order to create it) rather than a usability problem in DEDOS. The specific errors made are identified in Table 6.

Table 6. Errors encountered in Activity 3 and their frequency.

Error type	Frequency
User doesn't pin down items that need to be	8.7%
User pinned down an item that needed to be usable	8.7%

User chooses wrong functionality (selection instead of matching)	4.35%
User puts collaborative object in the individual zone	4.35%
User pinned down something that needs to be movable	4.35%

5.1.4 Activity 4

The average time to complete the creation of activity 4 (see Figure 23) was 6 minutes and 1.8 seconds. Five users did not complete the activity in the same manner it was originally created, and it was the most difficult to create. The difficulty to create this activity was due to the fact that it is a normal selection activity. However, the phrasing of the question and the inclusion of numbers made it appear like a math activity, challenging the users to determine what kind of functionality was necessary. This uncertainty allowed users to choose two different options in order to re-create the activity. In this case, the difficulties presented were not due to the usability of DEDOS, but rather the different interpretations that users had about how they should create the activity.

The common errors were: users not pinning down elements that needed to be static, and using the wrong kind of functionality based on the activity presented (2 users out of 17 made these mistakes). Five users did not finish due to time constraints; they are not represented in the frequency of error percentages. The specific errors made are identified in Table 7.

Table 7. Errors encountered in Activity 3 and their frequency.

Error type	Frequency	Number of users who did not complete the activity
User doesn't pin down items that need to be	11.76%	5
User uses Zones incorrectly (Adds two player Zones instead of one Collaborative Zone, one Player Zone)	11.76%	5
User chooses wrong functionality (Matching instead of Selection)	5.88%	5
User uses the math advanced options rather than using a text box	5.88%	5

5.1.5 Activity 5

The average time to complete the creation of activity 5 (see Figure 24) was 3 minutes, 28.8 seconds, with one user not completing the activity. In this activity, users made mistakes than in the other activites. The specific errors made are identified in Table 8.

Table 8. Errors encountered in Activity 5 and their frequency.

Error type	Frequency
User chooses advanced options instead of counter, but connected area to answer (one arrow)	4.35%
User employs multiple arrows rather than connecting the entire area, making all possible answers acceptable	4.35%
User adds counter to selectable cards, not the question prompt	4.35%

5.1.6 Activity 6

The average time to complete the creation of activity 6 (see Figure 25) was 2 minutes, 16.2 seconds with a 100% success rate. It must be noted that, due to time constraints, 3 of the users (23 total) were told to skip this activity.

The most common error was when users pinned down objects that needed to be movable, with 3 out of 20 people making this mistake. The specific errors made are identified in Table 9.

Table 9. Errors encountered in Activity 6 and their frequency.

Error type	Frequency	Number of users who did not complete the activity
User doesn't pin down things that should be fixed	5%	4
Placement of distinct images within SAME card (i.e. photos of 1 loaf of bread, 2 loaves of bread, etc all in same card)	5%	4
User pins down object that needs to be movable	5%	4
User created zones for each player	5%	

5.1.7 Activity 7

The average time to complete the creation of activity 7 (see Figure 26) was 5 minutes, 48.3 seconds with 100% success from the users. The specific errors made are identified in table 10 below.

Table 10. Errors encountered in Activity 7 and their frequency.

Error type	Frequency
User doesn't pin down things that should be fixed	4.35%
Does not create adequate zones (less created than needed)	4.35%
User places all images on one card when they need to be separate in order to be matched	17.39%
User created zones for each player	17.39%
User adds multiple arrows rather than connecting entire area	13.04%
Overlaps player zones so one zone contains two separate areas	17.39%

5.2 General analysis of the usability testing results

The errors found in the usability testing are not serious issues, and do not impede the usability of DEDOS-Editor. Users were never blocked from continuing the creation of an activity, and no one abandoned the creation process due to frustration, lack of understanding or lack of clarity within DEDOS-Editor. Many of the errors occurred due to lack of familiarity with the tool, or expectations that exist due to their previous experience with previous tools (such as JClic or Hot Potatoes). Given that all software has a learning curve, and with time users understand the functionality better, we have focused on the key issues that arose most often and have enough severity to be noted.

Table 11 shows the most common usability errors found, the location of the error, the severity of the error, and suggestions for improvement of DEDOS-Editor. Each error is classified according to its severity as High, Medium, or Low. Errors are given high severity if the activity cannot be completed successfully due to the error; this issue must be addressed immediately. A medium ranking means that some errors may occur, but the activity can still be successfully completed; these issues should be addressed. Low severity indicates that the application's functionality will not be affected, though improvement would help the users' overall experiences.

Table 11. Summary of usability errors encountered.

Error type	Location	Severity	Recommendation
Users place multiple, non-corresponding images on one card	Card editing	High	Include a note on the image card when users are adding images that states "*All images added to this card will be dispersed according to the number of players in the DEDOS-Player. Be sure that the images are similar in content*".
Users do not correctly use pins	Zone and image placement	Medium	Create a tooltip associated with the pins to communicate to user the pins' functions
Users add multiple arrows rather than connecting entire area	Functionality creation	Low	Add a tooltip to the matching/pairing tools that states "use the arrow to make individual elements selectable or an entire area"
Users are confused about zones (inadequate creation, unclear about which is which)	Activity creation	Low	Differentiate the zones in a clearer manner, through tooltips

One of the common errors is that user chooses inappropriate functionality (such as adding a counter to the incorrect card, or choosing matching rather than pairing). It is due to poor understanding of the activity. When designing their own activities, users will know which functionality is most appropriate, and thus, these issues do not affect the usability of DEDOS-Editor.

5.3 Survey findings

In addition to the observations made, the usability of DEDOS-Editor was evaluated by the users through a post-testing survey. A complete text of the survey can be found in the annex C of this document. In general, the results were favorable, and Table 12 shows the average responses to questions based on a Likert-like scale, with the following values: 1 is strongly disagree, 2 is disagree, 3 is undecided, 4 is agree and 5 is strongly agree.

Table 12. Average responses to the post-testing questionnaire.

Question	Average score
I would like to use DEDOS-Editor often when planning my class activities.	4.36
I had a sense of control while I used DEDOS-Editor.	4.09
DEDOS-Editor would help me be more productive in the classroom.	4.36
DEDOS-Editor would help me save time.	3.62
I was able to complete everything I wanted	4.32
The process of creating activities required few steps.	4.23
Creating activities in DEDOS-Editor did not require a lot of effort.	4.41
I encountered no errors while creating the activities.	3.33
It was easy to correct any errors I made.	4.18
I think it took an appropriate amount of time to create activities in DEDOS-Editor.	4.05
I quickly learned how to use DEDOS-Editor.	4.68
When I had to create the activity, it was easy to separate the common elements (the collaborative area) from the individual elements.	4.55
In the future, I think it will be difficult to remember how to create activities with DEDOS-Editor.	2.29
The application is satisfying; I am happy with how it works.	4.50
I would recommend the use of DEDOS to my co-workers in their classrooms.	4.57
I enjoyed using DEDOS-Editor.	4.72
DEDOS-Editor works as I would expect it to.	4.09

The average scores reflect a positive view of DEDOS-Editor. Only three factors scored below a 4, and for one of them ("*In the future, I think it will be difficult to remember how to create activities with DEDOS-Editor"*), a lower score indicates a positive view of the tool. The other two factors are: "*DEDOS-Editor would help me save time*" (scoring 3.62) and "*I encountered no errors while creating the activities*" (scoring 3.33).

The relatively low average score of 3.62 for "*DEDOS-Editor would help me save time*" could be due to the inexperience of the users, and as they use the tool more often, this opinion could change. In fact, two users cited the fact that with practice, they became more comfortable with the process, and required less time. These answers were in response to the open-ended question of "*Explain in detail if the process of designing collaborative activities, separating the common elements in the collaborative areas and the individual areas game player areas has been easy for you. What problems did you encounter? How would you improve the process?*" and were:

- "*It is a matter of practice, when u [ed. sic] have done some of them, you get the idea!"*

- *"I think you can find some problems at the beginning due to the inexperience with the tool, but once you try it, you find it is quite easy to create simple activities. First you have to be really aware of what part is aimed to the collaborative part and what to the individual part. The main problem is to get familiar at first with the counter, the associations, etc, but the steps are easy to follow after some minutes. All you need is practice and elaborate different kind of activities"*.

The relatively low average score of 3.33 to the question "*I encountered no errors while creating the activities*" could be due to the bug related to counter functionality that was present in DEDOS-Editor at the time of testing. This bug was cited in the post-questionnaire as hindrances to the users' experience. One user wrote: "*The problems I encountered while creating the activity have been, principally, with the counter functionality*"). Another user wrote, "*The only problem I encountered [ed. sic] was that one function did not always worked and you had to re-start the application*".

5.4 Usability problems and proposed solutions in DEDOS-Editor

This section highlights the usability issues identified through the observations of users and the users' responses to the post-testing questionnaire. There are four principal issues that arose during testing. A description of the issue, its effect on the user's experience and the usability of DEDOS-Editor and a proposed solution are outlined in the following subsections.

5.4.1 Misuse of image cards

There were cases when users would add multiple, non-corresponding images to a single image card. For example, an image card is meant to have pictures of one cat, and a user adds an image of one cat, an image of a dog, and an image of a donkey. DEDOS-Editor will disperse these images to the different players randomly. If the statement of the problem is "*Select the cat between the images*", sometimes the activity presented to the user will be wrong (e.g. when the statement of the problem and a picture of a dog are shown). This problem can make the activities impossible and block users from correctly using the DEDOS-Player, and therefore is given a high severity. The correct design of this activity requires the user to add three different image cards with distinct pictures of cats in the first card, a few images of dogs in the second one and finally, the last image card would contain various pictures of donkeys. With time, users creating activities within DEDOS-Editor should

understand how to add appropriate images to the image card, but given the gravity of the problem and its effect on DEDOS-Editor's usability, another solution is necessary.

The solution is as simple as including a note found on the image card when users add images that states: "*All images added to this card will be dispersed according to the number of players in the DEDOS-Player. Be sure that the images are similar in content*" (see

Figure 27).

All images added to this card will be displayed according to the number of players.
Be sure that the images are similar in content.,

Figure 27. Possible changes to the image card

5.4.2 Misunderstanding with the pins

The most common errors were related to the use of the pins. Some users forgot to pin down the objects that needed to be static or pinned down objects that needed to be movable. This would not affect the functionality of DEDOS-Editor; however, it could create huge problems when the activities are presented to students via the DEDOS-Player. If items are not pinned down but are supposed to be static, student users have complete liberty and can move the items anywhere they like, regardless if it is a common item in the collaborative zone or not. This could cause some students to collect all the items in their side of the tabletop, effectively blocking all other students from participating in the activity. If an object that is meant to be movable is pinned down, the students will be unable to interact with the DEDOS-Player correctly. Activities could become impossible. For example, if a student is given a matching activity and has to drag and drop an item into a basket, if the item is anchored, the activity cannot be solved, and the student cannot move on to the next one.

Users need to clearly understand when it is or is not appropriate to use the pins. This is something that users will understand over time and with use, however DEDOS-Editor would

benefit from a rollover title that clearly indicates the function and current state of the pin (see Figure 28).
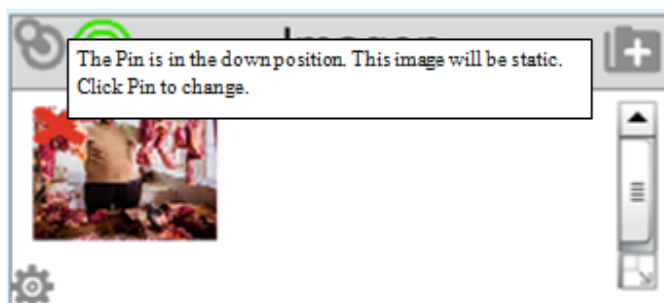
Figure 28. . Proposed tooltip that indicates the current status of the Pin.

5.4.3 Use of global functionality

There were cases where, in activities that have various correct responses; users connected each response to the collaborative zone with the matching or pairing arrows. In an activity with more than one solution, a user can connect the whole player zone to the collaborative zone, deeming all the content within the collaborative zone selectable. It is not necessary to add the functionality to each individual object.

This issue, while related to the usability, is not critical. It is more efficient for a user to connect the entire zone rather than individual objects (the time spent for the creation of the activity is less), but the outcome will be the same. For its low importance, since it does not affect the usability, this problem has a very low severity.

In order to provide users with a more efficient, stream-lined process, a tooltip that appears when the user has the cursor over the matching or pairing tools that says, "*use the arrow to make individual elements or an entire zone selectable*", as shown in Figure 29, informs the user of the two options he has.

Figure 29. Proposed tooltip that informs user of the two possibilities.

5.4.4 Confusion about zones

Currently, the zones are differentiated by color and by icon located in the upper-left corner (yellow and with multiple figure for collaborative zones, and blue with a single figure for the

individual zone). While for the majority of users it was clear which zone corresponds with which visibility it will have, some users were unclear in general about the purpose of the zones.
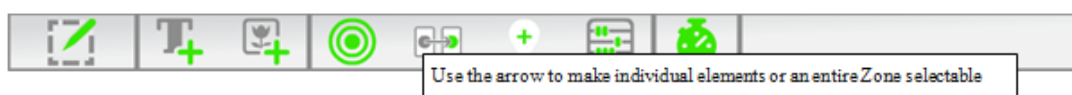
Some users would proportion a zone for each intended player. For example, if he is designing an activity for 4 players, the user created one collaborative zone and three separate individual zones. This is not at all necessary, and could affect how the DEDOS-Player appears on screen. It also is inefficient and makes DEDOS-Editor appear cluttered.

In other instances, users did not understand which zone was which, and would add items that needed to be collaboratively used to the individual zone instead of the collaborative zone and vice versa. All the users eventually realized that they had made this error and self-corrected, however, if DEDOS-Editor more clearly differentiated the zones, the error could be avoided entirely.

One possible solution would be, as shown in Figure 30, in addition to the colors and icons that are currently employed to differentiate the two zones, to add a rollover stating how users would view the specific zone. For example, a Game Zone would have the rollover "*This Game Zone will be visible to all users*", and the Player Zone's rollover would state, "*This player zone will be replicated to each student when they are using DEDOS-Player. If you want to change to collaborative zone, please click on the icon*".

Figure 30. Proposed tooltips that indicate to user the visibility of the areas.

5.5 Answers to research questions

In this section, the answers to the research questions posed in section 1.2 are answered, and an overall synopsis of the findings in relation to the document's goals is presented.

5.5.1 Does DEDOS-Editor satisfy the five key components as outlined by Nielsen?

As mentioned in section 1.2, Nielsen's five key components of usability included: learnability, efficiency, memorability, errors, and satisfaction. This section investigates each component individually, with the support of the observations and user feedback.

A. Learnability

If a user is unable to easily learn the functioning of DEDOS-Editor, its usability suffers. To measure the learnability of DEDOS-Editor, the statement "*I quickly learned how to use DEDOS-Editor*" was evaluated on a scale of 1 (strongly disagree) to 5 (strongly agree). The average answer of the 23 users was 4.68. This high score strongly indicates that DEDOS-Editor is very easy to learn and users spend less time learning how interacting with this tool.

B. Efficiency

A factor of the usability of DEDOS-Editor is how efficient the activity creating process is, and if the time spent creating said activities is appropriate. To evaluate the efficiency of DEDOS-Editor, the statement "*I think it took an appropriate amount of time to create activities in DEDOS-Editor*" was evaluated on a scale of 1 (strongly disagree) to 5 (strongly agree). The average answer of the 23 users was 4.05. Additionally, the statement "*The process of creating activities required few steps*" was evaluated, with an average score of 4.23. These high scores strongly indicate that DEDOS-Editor is efficient from the users' perspective.

C. Memorability

If a user cannot remember how to use a tool in the future, his experience will be soured, and the usability of the tool is compromised. To check that DEDOS-Editor memorability of DEDOS-Editor, the statement "*In the future, I think it will be difficult*

to remember how to create activities with DEDOS-Editor" was evaluated on a scale of 1 (strongly disagree) to 5 (strongly agree). The average answer of the 23 users was 2.29. This low score demonstrates that users believe it will be easy to remember the process of activity creation, and thus, DEDOS-Editor features good memorability.

D. Errors

An important aspect of usability is the capacity that users have to overcome and work around errors. In order to understand the users' perspectives on the occurrence of errors and their ability to manage the errors, the statement "*I encountered no errors while creating the activities*" was first evaluated. It received the score of 3.33; 6 of the 23 users strongly agreed or agreed that they encountered no errors in the activity, which means that the remaining 17 users did. These errors could be due to a bug with counters in mathematical activities (if a user selected the counter tool and then placed it in the trash to remove it, the tool disappeared entirely from the tool bar, forcing users to restart the application).

To better understand the impact of the errors on the users' experience, the statement "*It was easy to correct any errors I made*" was also evaluated. It received an average score of 4.18, showing that, for most users, it is not difficult to confront and solve errors in DEDOS-Editor.

E. Satisfaction

To gauge user satisfaction, the statement "*The application is satisfying; I am happy with how it works*" was presented. It received a very high average score of 4.5. In addition to this statement, the question "*Overall, how would you rate your experience with DEDOS-Editor this application/software?*" was proposed. Of the 23 users, 2 users rated the experience as "excellent", 18 users said it was "*very good*" and 3 users rated it as "*good*". There were no negative ratings, and it is clear that DEDOS-Editor offers a satisfying experience to users.

5.5.2 Where does the tool fall short in providing a quality user experience?

The primary issues found were: the misuse of images cards; the understanding of the pin function; the understanding of creating global functionality; and confusion about the zones.

These shortcomings are outlined in detail in section 5.4.

5.5.3. What changes can be made to improve DEDOS-Editor?

To evaluate this question, a qualitative approach was taken. In the post-testing questionnaire users were asked: "*How could DEDOS-Editor be improved?*" The most common responses include:

- 4 users suggested adding more activity types, such as "adding new functions, like coloring a picture, or doing a puzzle", and adding sound capabilities to activities.
- 5 users included comments on the "overly" simplistic, visually "boring" layout, and that the lack of variety of colors could all be improved.

5.5.4. What are the best and worst aspects of the DEDOS-Editor?

To further understand the tool's strengths and shortcomings, we asked what its best and worst aspects are. The feedback includes three comments saying that the DEDOS-Editor is intuitive, which implies a high degree of usability. Other users enjoyed the format and concept of DEDOS, especially its touchscreen possibilities. Some of the noteworthy, positive statements included:

- "For me the best part is that DEDOS-Editor is very intuitive."
- "It's easy, intuitive, and fun to use." (*"Es muy fácil, intuitivo y divertido de usar."*)
- "[The best part is] the easiness of creation of activities.
- "I think the best part is that is a touchable application because kids love to touch things and I think it helps the learning process. I think it is also very useful that you can modify the mathematical value of the images in the same window without needing a new one."
- "I think the best is that you can create activities for the mutitouch table which can be really enjoyable for children. And for the teachers is also an advantage to create this kind of exercises with the PC."

The worst aspects pointed out by the users are primarily related to design and the tools interface. Two users pointed out the low-quality resolution of the images when they are shown in the player. Another said that if DEDOS-Editor were more attractive, more people would be interested in using it. One suggested that if there were more variety of colors and personalization, it would be a better tool. Three users suggest adding more activities in addition to those that alreadt exist. Some interesting comments include:

- "The images are too small. You have to delete the text "write here" when you want to write the text, it would be easier if you click on it and the text disappears."

- "I think that it could have more kinds of activities so that children or people in general, may enjoy with a really huge variety of activities."
- "The DEDOS-Editor could be improved with included much activities of the other types."

6. Conclusions and future research

Overall, the results of the usability testing of DEDOS-Editor are quite positive. It meets the criteria of usability that it was tested against, and provides users with a learnable, efficient, memorable, and satisfying experience that allows users to mitigate errors in an easy way. Of the four usability issues classified, only one is a high-severity problem. These four problems all have simple solutions that would not cause huge changes to the current too or create difficult, unnecessary work to developers.

In the future, if changes are implemented to improve the usability of DEDOS-Editor, it is advisable to evaluate these changes appropriately; with every iteration of the tool, testing should be done to confirm that DEDOS-Editor continues to be a user-friendly, enjoyable platform.

As DEDOS-Editor is implemented in more realistic situations (teachers creating activities for their classes and students completing the activities), it is important to continue to analyze the usability of the tool. As mentioned before, the participants in our study are students, not working teachers, and thus, their experiences and expectations may not reflect those of working teachers. A long-term study based on teachers and classrooms that implement DEDOS-Editor will better reflect its use in a real-life situation, and will also lead to understanding the functioning and usability of the DEDOS-Player, another part of the complete DEDOS project that must be investigated.

The limitations of this study can be divided into two types: limitations of the users, and technical limitations. On the one hand, our user population was of current students who are training to be teachers. While some have completed their student teaching obligations, not all have had direct teaching experience as they are first year education students. Without this experience, they have a more limited view of classroom dynamics and the model of a successful classroom activity. Due to their lack of experience, their predicted use of DEDOS could have certain inaccuracies. On the other hand, owing to the current development of the tool, there are some technical issues such as DEDOS-Editor had a few bugs, hindering the user experience. One of the most grievous bugs was that if a user selected the counter tool and then placed it in the trash to remove it, the tool disappeared entirely from the tool bar, forcing users to later restart the program to have complete functionality. These two issues

resulted in some users spending more time than necessary on an activity, since they had to restart the program.

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Annex A. Pre-questionnaire

These questions are about an application that teachers can use to create games and activities for their primary school or special needs students.

1. Please rate in order of importance, 1 being the top priority and 4 being the lowest priority:

- The application is useful and would help my class learn and be more productive.
- The application is easy to use; the children understand how to use it and it is easy for me to create activities.
- The application is easy to learn; once the students and I know how it works, we have no problems remembering how to use it.
- The application is satisfying; I am happy with how it works and so are my students.

2. Please rate in the order what you believe <u>your students</u> would find most important, 1 being the top priority and 4 being the lowest priority:

- The application is useful and would help me learn about the subject.
- The application is easy to use; I easily understand how to play with it.
- The application is easy to learn; once I know how it works, I have no problem remembering how to use it.
- The application is satisfying; I enjoy using it.

3. What is more important to you?

- Your experience using the application
- Your students' experience using the application

4. What would the most important aspect be for you as the teacher? Please rate from 1 to 5, 1 being the top priority and 5 being the lowest priority.

- How easy it is to create games/activities.
- How easy it is to change the level of difficulty of activities in the game.
- How the application appears visually.

- How easy it is to remember the process of activity creation once you know how to create activities.

- How effective the application is at reinforcing ideas from the subject.

5. Have you ever used an application/software with your students? Yes/No

5a. If yes, what applications or software have you used? (fill in blank)

5b. How would you rate this application/software?
1–Best, 2-Very good, 3–Good,   4-Average, 5-Below Average, 6-Awful.

6. What are the best parts of this software/application? (fill in blank)

7. What are the worst parts of this software/application? (fill in blank)

Annex B. Script used during testing day

Thank you for participating in our usability evaluation. I will read from this script throughout our session to make sure I ask the same questions during each evaluation of the program.

I am a Master student who is evaluating the usability of DEDOS-Editor. Today, we will ask you to perform some specific tasks in DEDOS-Editor. These activities are designed to evaluate how well the software works for you; it is in no way a test of your knowledge or skills, but rather a test of the software itself. Please be honest with us, we will not be offended by anything, and your criticism will help us to evaluate the strong and weak points in the software design.

I will first explain to you the different elements of the program and the process of creating the different activities. There are seven different types of activities total. You will then be given time to create the seven different activities.

We expect these tasks should take about an hour and a half, and will be followed by a questionnaire, which will take about 15 minutes to complete.

If at any time you need take a break, please let me know. Do you have any questions?

FIRST: Let me explain the different parts of DEDOS-Editor. When you first open the program, your screen will look like this. DEDOS-Editor has two different modes: "*Basic Mode*" and "*Advanced mode*". For our purposes, we need to use "*Advanced mode*". The white area found in the center is the editing area. To create an activity, you must drag and drop the different icons into the editing area.

The left side is the activity preview area. Using the "*add*" button, you can add more activities to be used within the same game.

The green icons along the top are divided by function into four sections:

- The first function is to: create a zone. To make activities you need to create a zone, which can either be a player zone which is visible to individual or groups of players or game zone, which is where the games' actions take place.

- The second function in the toolbar is to: add objects to the zone (text and images).
  - Text card. You can drag and drop this tool onto a zone in order to add text.
  - Image card. You can drag and drop this tool onto a zone in order to add an image. To upload an image, you must click on the top right corner and choose the image file you want to be placed in the zone.

  Both the text and image cards share three characteristics: In the top left corner, you can see a pin. If you push the pin in, you anchor the cards position, making it unmovable unless you select the pin again. In the bottom left corner, you can select advanced options, and make the text box selectable, turnable, and resizable. The bottom right corner is an arrow. You can select this area to change the size of your textbox.

- The next area is the interaction area:
  - The first button, a green target, can be dragged and dropped in order to make an object selectable. By adding it to an object, that object can be selected.
  - The next button is the matching button. When you select this Interaction, you pair two objects together.
  - The third button is the paths button, which we are not using for this session.
  - The fourth button is the counter, which can be used to create math activities. When you drag and drop the counter onto an object, you click on it in order to change the number.

Finally, in the bottom right corner, you can see the Trashcan. If you wish to remove anything from the Editor area, you simply drag and drop it into the trashcan.

EXAMPLE ACTIVITIES

I am going to show you how to do the three main activities that we will encounter today. To create some of the activities, you will have to combine these different types of activities.

Selection activity: First, add two zones to the editor area, and make one for the game and one for the players. To create a new editor zone, we click on "*Add*" on the bottom left corner, found in the preview sidebar.

- In the game zone, we add text, asking the question, "Where is the cat?"
- In the players' zone, we add three images, one of a cat and the others of different animals. Then, we drag and drop the Select button onto the image of the Cat, indicating that this is the correct answer.

Any questions?

Matching activity: First, add two zones to the editor area, and make one for the game and one for the players. In the game zone, we add text, saying "*Match the animals to the color that they are*".

We create 3 separate textboxes, all in the player zone: "Orange" (Fox), "Brown" (Chimp) and "White" (Hedgehog). We click the pin to push it in and fix the text boxes in place.

Then, in the player's zone, we add the three photos of the animals by dragging and dropping the image object three separate times. We add photos of the fox, the chimp, and the porcupine.

Finally, we add the matching interaction by dragging and dropping the matching arrow onto an animal and connecting the arrowhead to the corresponding color. We do this for all the images.

The last activity is the Math activity.

Again, we add two zones to the editor area, and make one for the game and one for the players. In the game zone, we add a text box to create a math problem. "*Sarah's mom says she can only take care of 5 cats. Select five cats.*"

The activities that you need to do now are:

1. Selection activity with three possible answers, only 1 correct.
2. Matching activity with three pairs.
3. Simple math activity.
4. Selection activity with various correct answers.
5. Matching activity with more than three pairs.

6. A more complex math activity.

7. An activity that mixes selection and math."

6. A more complex math activity.

Annex C. Post-testing questionnaire

These questions are about your experience creating activities in the DEDOS Editor. Please answer honestly, your answers will help us to improve DEDOS-Editor, and are kept anonymous.

SCALE FOR QUESTIONS 1 TO 17

- 1 is Strongly Disagree
- 2 is Disagree
- 3 is Undecided
- 4 is Agree
- 5 is Strongly Agree

QUESTIONS

1. I would like to use DEDOS-Editor often when planning my class activities.
2. I had a sense of control while I used DEDOS-Editor.
3. DEDOS-Editor would help me be more productive in the classroom.
4. DEDOS-Editor would help me save time.
5. I was able to complete everything I wanted to.
6. The process of creating activities required few steps.
7. Creating activities in DEDOS-Editor did not require a lot of effort.
8. I encountered no errors while creating the activities.
9. It was easy to correct any errors I made.
10. I think it took an appropriate amount of time to create activities in DEDOS-Editor.
11. I quickly learned how to use DEDOS-Editor.
12. When I had to create the activity, it was easy to separate the common elements (the collaborative area) from the individual elements.
13. In the future, I think it will be difficult to remember how to create activities with DEDOS-Editor.
14. The application is satisfying; I am happy with how it works.
15. I would recommend the use of DEDOS to my co-workers in their classrooms.

16. I enjoyed using DEDOS-Editor.

17. DEDOS-Editor works as I would expect it to.

18. Overall, how would you rate your experience with DEDOS-Editor this application/software? Excellent, very good, good, average, poor, very poor and horrible.

19. Explain in detail if the process of designing collaborative activities, separating the common elements in the collaborative areas and the individual areas game player areas has been easy for you. What problems did you encounter? How would you improve the process?

20. What are the best parts of DEDOS-Editor?

21. What are the worst parts of DEDOS-Editor?

22. How could DEDOS-Editor be improved?

23. Please check the option that reflects your years of experience working in education including the internship in schools (if you are in the third or fourth year): 0-2 years, 3-5 years, 6-8 years, 8+ years.

24. Please select your Degree: Pre-Primary school / Primary school

25. Please choose your year in the Degree: 1 / 2 / 3 / 4 / 5

26. Have you previously used DEDOS in the past? Yes / No

27. Please indicate your gender. Male/Female

28. Comments and/or suggestions.