DOCTORAL THESIS

Leveraging natural interaction and direct manipulation as catalyzers of digital evolution in education

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LEVERAGING NATURAL INTERACTION AND DIRECT MANIPULATION AS CATALYZERS OF DIGITAL EVOLUTION IN EDUCATION

APROVECHANDO LA INTERACCIÓN NATURAL Y LA MANIPULACIÓN DIRECTA COMO CATALIZADORES DE LA EVOLUCIÓN DIGITAL EN EL SECTOR EDUCATIVO

Realizada por **Don David Roldán Álvarez** bajo su dirección y supervisión en el Departamento de Ciencias de la Computación, Arquitectura de Computadores, Lenguajes y Sistemas Informáticos y Estadística e Investigación Operativa, que presenta para la obtención del Grado de Doctor por la Universidad Rey Juan Carlos.

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ABSTRACT

Information and Communications Technology (ICT) offers multiple possibilities for creating educational activities and implementing them in classrooms. The 'Survey of Schools: ICT in Education' sheds light on the use of ICT in education. Firstly, most students think that the use of technology during their learning process is interesting. They are motivated to learn through this approach since they can use ICT to perform tasks on several devices, not only in the classroom, but also at their homes. Secondly, the educational sector agrees on the relevance that ICT could have in carrying out different activities, in addition to the positive impact it could exert on students. However, only between 20-25% of students use ICT in the classroom. In this regard, a study conducted by the Instituto de Técnicas Educativas in Spain showed that 45% of teachers do not use ICT due to their lack of training, and that 31% do not use ICT because they feel insecure. In addition, the wide range of educational tools available makes it difficult to choose the appropriate one for each scenario. Therefore, it is necessary to provide the education sector with tools which are flexible, can be adapted to their needs, and are easy to use by users without advanced technical knowledge.

In this context, this work has been carried out with the goal of evaluating which features of an application could be important when being effectively used by teachers, as well as the benefits that the inclusion of technology could offer to students in childhood education, primary education and special needs education. In general, this work is oriented towards the evaluation of three factors: i) providing appropriate tools which allow the creation of content without technology being an obstacle during the design process; ii) exploring the benefits of the new interaction paradigm provided by new devices, such as touch interaction; and iii) studying the adaptability of content so that users can generate different learning scenarios without having to change that content.

To study these factors, we have implemented and used an authoring tool – DEDOS-Editor – to create educational activities, and two players – DEDOS-Player and DEDOS-Web – which enable the use of these activities on most of the devices available on the market. These players also allow several additional parameters to be configured which facilitate the reshaping of the activities in order to create different learning scenarios and adapt them to the pedagogical needs which exist in the various education levels where these tools are used. To test the benefits of ICT in the classroom, we

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conducted experiments with students from three educational levels to compare the effectiveness of touch technology devices versus traditional learning methods.

The studies carried out aim to evaluate whether touch technology – which is widely used in society – could act as a bridge to integrate ICT in education. In this scenario, its use with educational goals is not widespread among young students who could benefit from the interaction offered by touch devices that require neither a mouse nor a keyboard. Reviewing the literature, not much can be found regarding empirical studies that help to understand how technological resources could be integrated in classrooms, and which benefits they could offer to students' learning.

On the one hand, the evaluation of DEDOS-Editor shows how the ease with which users – in our case future teachers – learn to use an authoring tool to create their own digital content is impacted by the tool's interface and the creation metaphor used. The data gathered in this work shows how a direct manipulation paradigm and a consistent creation metaphor for creating activities enables users who have experience with the tool to become experts in a short amount of time.

On the other hand, the learning experiments across several education levels – childhood education, primary education and special needs education – shed light on the possible benefits that technology could offer to these students. The flexibility of DEDOS-Editor and DEDOS-Player allowed educational activities to be carried out in different learning levels and enabled diverse learning scenarios to be created. The results show that students who used technological elements experienced better learning than those students who solved the activities in a more traditional way. Moreover, several teachers who were initially sceptical about the use of technology by young students later recognised the benefits of using technology in the classroom, causing them to consider using such technology regularly.

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CHAPTER 1: INTRODUCTION

This introductory chapter presents the general motivation which led to the work presented in this thesis, and which is more thoroughly detailed in the second chapter. Once the general background of the thesis is explained, its objectives and the work proposal are established. Lastly, the structure of this document is included.

1.1 Motivation

During the last several decades, Information and Communications Technology (ICT) has gradually been integrated in society, in some scenarios becoming almost indispensable for the fulfilment of daily life activities. In Spain, the number of homes that have any type of computer has increased almost 20 points in the last 10 years, from 57.2% in 2006 to 77.1% in 2016, according to the National Statistics Institute of Spain. The rise of households with access to the Internet has been even greater, evolving from a moderate 41.1% in 2006 to 81.9% in 2016 (INE, 2007; INE, 2016). This highlights the fact that nowadays there are more Spanish homes with Internet than with personal computers.

Not only has the number of internet users increased, but so has the World Wide Web itself. From its creation in 1992 (Berners-Lee et al., 2000) as a network of fundamentally passive information, the Internet has socially evolved into the current Web 2.0: a network composed of not only information, but also interaction, populated by new social concepts such as blogs, wikis, forums, chats and social networks (Goodchild, 2007). Through this kind of web, users can share information in a more collaborative manner, recognising the value of the content provided by users as well as the relationships among them.

Parallel to the evolution of the Internet as an interaction tool, the devices used to connect to the online network have undergone a similar evolution (Teléfonica, 2011). Following this, the personal computer, introduced in Spain in the 1980s, has gradually abandoned the desktop and its classic peripheral devices to enrich the ICT world with mobile devices and functionalities distributed in the cloud (Google, 2016). Such changes have also brought new ways of interaction, both individually and collectively.

In this regard, it is interesting to point out the impact of touch devices, which are now popular thanks to both smartphones and digital tablets. In 1993 there were tactile devices such as 'Touchmate' and digital cameras such as the Canon IonPC model, and this technology joined mobile phones in 1994 with the IBM Simon and PDAs with

operative systems such as Palm OS, Blackberry OS and Windows CE. However, it was not until the arrival of multi-touch interfaces on smartphones – Apple's iPhone in 2007 and Android's HTC Dream in 2008 – that this technology became popular. These first smartphone concepts, which achieved natural multi-touch interaction, linked in a mostly unnoticeable way the world outside of the desktop with the creative possibilities of information and social interaction of a computer. Although the first tablet, Microsoft Tablet PC, was created in 2001, these devices did not become popular until the introduction of the iPad in 2010, three years after the first appearance of the current smartphones. Thus, the use of tablets has not become widespread until the last five years (see Figure 1).
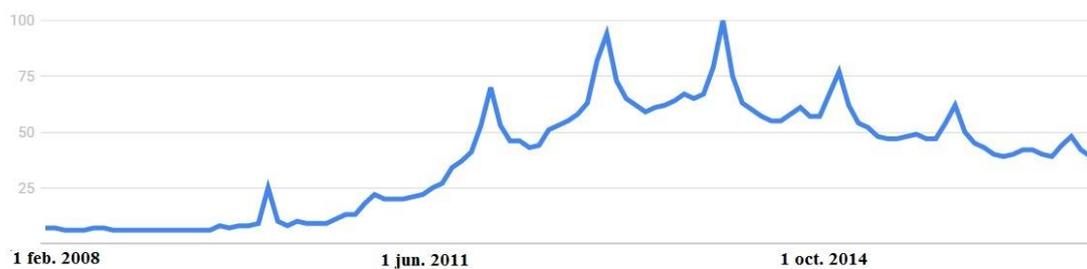
Figure 1. Results of the search of the term 'tablet' according to Google Trends

Together with the popularisation of multi-touch interfaces, in recent years other technologies and interaction paradigms have made a qualitative leap to the masses. Examples range from voice interfaces with products such as Siri, Cortana, Alexa and Google Now (developed by Apple, Microsoft, Amazon and Google, respectively) to augmented reality, which offers more direct interaction with the environment through devices. Phenomena like Pokemon Go shows us how the use of augmented reality, combined with the integration and physical interaction provided by smartphones and digital tablets, can become a mass phenomenon among youngsters (Serina et al., 2016).

Therefore, in the last few decades, the increased popularity of new ways of interaction with devices, the environment and other users has come to change society as well as the way in which ICT is used. These new possibilities open complementary alternatives in education, where the paradigm of the master class still has a major role. Now, students can access seminars or conferences by leading figures, or content designed by teachers or other students from every corner of the world, through videos, forums, chats, etc. Such information is accessible from every place and every device, always with

the capability of browsing from one type of content to another in an instant. In this context, the purpose of the teacher should evolve to take greater advantage of the digital era.

The poll 'Survey of Schools: ICT in Education' examines the use of ICT in education (European Union, 2013). Firstly, this report highlighted that students believed the use of technology in their daily learning was attractive. They felt motivated to learn using ICT, since it allows them to perform educational activities from their home by using their own electronic devices. Secondly, the report explained that both teachers and principals from the schools agreed that the use of technology captures the attention of the students. However, one of the conclusions of this report shows that only between 20% and 25% of the students are taught by teachers with digital competences who do not face any obstacles when trying to use technology in the classroom.

At the moment, a vast number of educational institutions use personal computers to perform ICT activities (European Union, 2013). However, such computers' characteristics and peripheral devices do not promote collaborative learning which encourages the interchange of ideas and an environment of discussion among the students so that they can come to a common solution (Slavin, 1980). Personal computers also present another set of issues, such as the difficulty of synthesising all the users' contributions by only one person (Rogers et al., 2009), or the incorrect visualisation of the content due to the size of the screen when more than one user interacts with the device (Pawar et al., 2007). In this context, interactive whiteboards and multi-touch surfaces have started to appear in the classroom, due to their large size which is suitable for collaborative activities (Jones et al., 2011; Dillenbourg et al., 2011). With these surfaces, students can gather around and can participate in solving problems jointly. These devices also facilitate communication and face-to-face collaboration.

Nevertheless, interactive whiteboards and multi-touch tabletops present some concerns regarding their mobility, which does not allow access to information from everywhere. This factor hinders content sharing from outside the classroom or the place where they are installed. In this scenario, digital tablets are presented as devices which facilitate ubiquitous learning and enable access to personalised content for each student regardless their location (West, 2013). Although it is complicated to design a collaborative environment through only one device due to its size, it is possible for several tablets to be interconnected; this allows multiple students to access the same content and

enables them to interact in the same workspace. All the available hardware is complemented with software such as educational apps for various topics, authoring tools to turn teachers into designers of their own content, and MOOCs (*Massive Open Online Courses*), which have become popular in the last few years. Nonetheless, most educational applications only address one topic and usually can be used from only one type of device; this hinders their adaptation to other topics and their use from other devices, limiting their usability (Hutchful et al., 2010). Authoring tools seek to address this problem, allowing teachers to create their own educational activities for the topic they desire. However, in this case it seems that the inappropriate design of the graphical user interface and the lack of training prevents teachers without technical knowledge from using these tools to their full potential, which in turn hampers their adoption (Roldan-Alvarez et al., 2016). Lastly, the explosion of MOOCs has allowed teachers to distribute their knowledge globally, enabling everyone with an Internet connection to access a great variety of courses on different topics. However, MOOCs do not address education at early ages, and the existing literature about this subject is only centred on students' perceptions of MOOCs and not on their learning through this resource (Garrido et al., 2015).

In light of all that has been said in the previous paragraphs, it seems clear that technology has become integrated into society in a deeper, smoother and faster way than in education, providing new possibilities for daily life with obvious potential for teaching. This situation leads us to think about which factors could be relevant in order to enhance the adoption and inclusion of technology in the classroom, and the expansion of this learning environment outside the classic walls of educational institutions. In this work, three factors are considered in order to help to initiate change in the educational paradigm: content creation, new capabilities for interaction (social and device-based), and adaption of the content to different learning environments.

Firstly, the creation of appropriate content for students from various educational levels and contexts is a key function of education professionals. Therefore, it is necessary to develop authoring tools which allow these professionals to design educational activities without experiencing technology as an obstacle in this creative process. This content should be reused, modified and shared in an effortless way. It should also be easy to consume from any location, adapting itself to the device where it is consumed. This poses the challenge of allowing the activities to be carried out on nearly all the devices available

nowadays (personal computers, interactive whiteboards, digital tablets, multi-touch surfaces and smartphones).

The second factor refers to the new paradigms of digital interaction: a natural interaction with the device, and social interaction through ICT. Touch interaction, popularised with the introduction of smartphones and digital tablets, eliminates the need for an intermediate peripheral device such as a mouse or keyboard to manipulate the applications and content; this is particularly suitable for those students with limited motor skills (Zuckerman et al., 2005). Thanks to this new possibility to interact with the content in a more direct and natural way, collaboration among students is enhanced since it allows them to work on the same device at the same time (Piper et al., 2006; Rogers & Lindley, 2004). This environment helps students to develop their social skills and their knowledge acquisition (Roldán-Álvarez et al., 2014).

The third factor, which is closely related to the previous one, is the adaptability of the content; that is to say, the ability of the teachers to create different learning environments with the same content. These scenarios could vary considerably depending on the available technology, the location of the students, the size of the group and the educational goals, among others. For instance, if the teacher has digital tablets in his/her classroom, he/she should be able to present the educational content on those devices, and the students could then interact with it in an individual way. However, if the teacher has an interactive whiteboard, the content could be adapted to a more collaborative environment where several students could interact at the same time. In this example, the application should take into account the number of students that could participate in one activity. It would be unfeasible for a group of 20 students to perform the activities on an interactive whiteboard at the same time, but it would be reasonable for each student to complete the activities on their own digital tablet. The pedagogical goals that the teacher wants to achieve are also a key factor when performing educational activities, since, for example, it should be possible to adapt the same content to collaborative and competitive environments. Due to all these factors, it is important that applications allow a certain flexibility which helps the teacher not only to create educational content, but also to use such content in different scenarios.

Focusing on these three factors, three applications have been developed. The first is DEDOS-Editor, an authoring tool based on natural interaction paradigms and direct manipulation which allows the design of card-based educational activities. Second is

DEDOS-Player, an application which allows users to perform the activities designed with DEDOS-Editor on multiple devices (personal computers, interactive whiteboards, tablets and multi-touch tabletops) and modify the way of doing the activities depending on the goals the teacher wants to achieve or the device used. Lastly is DEDOS-Web, an evolution of DEDOS-Player through which users can perform the activities designed with DEDOS-Editor on any device with Internet connectivity. All these tools have been evaluated according to the previously mentioned factors, by studying the influence of natural interaction paradigms on the process of digital content creation and its consumption in learning environments, taking into account variables such as collaboration, interaction among the students and learning.

1.2 Goals and proposal

This work has been developed with the double goal of evaluating how the graphical user interface of an authoring tool affects the learning curve of future teachers, and researching the benefits that could be brought by including technology in the classroom during childhood education, primary education and special needs education. In order to study these issues, we have used an authoring tool which supports the design of educational activities, along with two players that allow such activities to be implemented on most devices that are available at educational institutions. The configuration of the application allows it to be automatically adapted to different learning environments as required by teachers. The details of this feature are explained throughout this document.

The authoring tool aims to transform teachers into designers and facilitators of educational digital content, and to increase the adoption of this kind of tool as a key factor in accelerating digital transformation in the classroom. Part of this work emphasises the importance of learning abilities in order to prevent rejection or abandonment of a certain tool provided to the teachers, as well as how a tool's acceptance could be related to the interaction paradigm and the creation metaphor.

Little by little in education, touch technologies which modify the traditional ways of interacting with computers are being included in the classroom. Typified mostly by digital tablets and interactive whiteboards, this kind of technology draws ICT near to those students who have not fully developed their motor skills, and therefore have difficulty when trying to manage a mouse or a keyboard. This also includes pupils from

childhood education and special needs education. This work seeks to evaluate the use of touch technology in education, identifying its benefits and limitations in order to help determine how such technology could be included in the education sector in a way that is appropriate and non-intrusive.

Furthermore, it is necessary to analyse how the use of ICT affects learning, and whether it provides additional benefits apart from better knowledge acquisition. In this context, the adoption of ICT at early ages could be crucial in order to adapt traditional classrooms to the digital era.

As time goes on, the use of technology by students in their early years is increasing both in schools and in the home. However, the literature shows that nowadays there are not enough empirical studies to determine whether the use of technology by these kinds of students is suitable for their learning. Therefore, in this work several learning experiments have been conducted in childhood education and primary education. Moreover, several experiments with students with intellectual disabilities (ID) and Autism Spectrum Disorder (ASD) have been performed in order to study how the use of ICT affects them.

1.3 Document structure

The present document is divided into four main sections: motivation, developments, evaluation, and conclusions and future work. Each of these parts is composed of several chapters, amounting to 10 in total:

- Part I. Chapter 1: In the present chapter the background of this work is explained, identifying the technological advances that affect the education sector, detecting which factors should be taken into account and proposing the goals to be achieved with this thesis.

- Part I. Chapter 2: This chapter describes the state of the art of the use of technology in classrooms, particularly in childhood education, primary education and special education. This chapter outlines the criteria which make touch technology suitable for these education levels, along with some tools through which teacher can integrate technological elements in their classrooms.

- Part II. Chapter 3: This chapter presents the studies and the design decisions which were made before developing the applications. DEDOS-Editor, an authoring tool which allows the creation of educational activities which can be performed on

multiple devices, is then described. This is followed by an explanation of the data model used to represent the information about the educational projects and allow communication with other applications which use this model.

- Part II. Chapter 4: This chapter describes DEDOS-Player, a tool which allows the activities designed with DEDOS-Editor to be played on a large variety of devices, such as personal computers, interactive whiteboards, digital tablets and multi-touch tabletops.

- Part II. Chapter 5: This chapter presents DEDOS-Web, a development which transfers the functionality of DEDOS-Player to the network, broadening the availability of the tool and its access from any kind of device with access to the Internet.

- Part II. Chapter 6: This chapter shows the details and the results of the usability evaluation of DEDOS-Editor, which showcases the strengths and limitations of this authoring tool by comparing it to another popular tool within the Spanish educational sector.

- Part III. Chapters 7, 8 and 9: These chapters detail the studies performed in the areas of childhood education, primary education and special needs education. These learning experiments help to determine the benefits and limitations of the integration of technology elements in these education levels.

- Part IV. Chapter 10: This chapter includes the conclusions of this work, details on current and future work, and the scientific contributions made by this thesis.

- Bibliography and URLs: Finally, this section includes the bibliography and the URLs cited throughout this document.

CHAPTER 2: STATE OF THE ART

The boom of the information society has led to a shift in the way content is created and found, which has varied as access to the Internet has expanded throughout the population. In recent years, there have been changes in the way people live, interact, communicate, learn and access knowledge. The Internet allows each user to access every online resource in an equal manner. In the education sector, this situation has caused some challenges to arise with regard to adapting to these new societal changes. In the education environment, books have gradually been complemented with technological elements such as computers, interactive whiteboards and digital tablets, among others (Galanouli et al., 2004). For this reason, subjects related to ICT have been included within the basic learning plans of future teachers in order to allow them to acquire digital competences. Accordingly, new teachers are becoming familiar with technology, and as time passes, its use is becoming more efficient (European Union, 2013). However, the inclusion of technology in the classroom is does not occur as smoothly as it does in daily life (Dotong et al., 2016). Therefore, it is necessary to analyse the barriers that hinder an appropriate inclusion of ICT in education. This chapter details the current situation of technology in education, explaining the adoption challenges, how technology is entering the classroom, some of the tools used to create digital content and, lastly, some of the experiments that have been conducted in different education levels.

2.1 Background

The interest in technology extends to nearly all education institutions, where both teachers and institutions seek to use ICT to enhance students' skills (Anderson, 2008). The integration of ICT in teaching and learning has become a main goal in schools all around the globe (Vanderlinde et al., 2009). In this context, ICT is perceived as a tool which helps students to master the skills required to use information and communications systems (Anderson, 2008), to promote self-regulated learning strategies (Karabenick, 2011) and to change the way of interaction inside the classroom, among others (Anderson, 2002). Moreover, ICT is a key factor in facilitating the creation of student-centred learning environments (McKnight et al., 2016). Due to all these factors, along with the positive impact of using technology in students' learning (BECTA, 2007), researchers are looking for those key points that support ICT as a tool for teaching and learning (Cox, 2008).

Not using ICT in the classroom could be inconvenient for students, since if they do not have access to technology, they would be denied the opportunity to learn the skills and competences needed to become full participants in an increasingly globalised world where technology is used more and more (UNESCO, 2008). At the same time, it should be noted that having access to technology in the classroom does not guarantee that learning will be enhanced; this is because it is possible that, due to a lack of knowledge, technology could be used to achieve inappropriate or outdated goals (Selwyn, 2016). Moreover, the use of ICT in education should be supported by adequate policies (Tondeur et al., 2008) in all education levels, as well as effective professional training for teachers (Lim, 2007).

Nowadays there are numerous efforts to include technology in the classroom, although a very low percentage of students are taught by teachers with advanced digital competences (Levi & Ben-Ari, 2007; European Union, 2013). This information points to the need to improve the digital competences of teachers so that they can effectively use ICT and take advantage of its maximum potential. In Spain, another study showed that 45% of teachers do not use technology due to their lack of training, and around 31% do not use ICT because they feel insecure (CECE, 2012).

The problem is exacerbated by the rigidity of educational tools that can be found on the market, since in most cases these do not satisfy the needs of teachers (Hutchul et al., 2010). One approach to solve this problem is to direct efforts towards the development of educational applications that can satisfy particular needs. One example could be the creation of an application that more clearly explains the planets of the solar system (Kelly et al., 2010). However, implementing this kind of application is a daunting task which involves a costly process and a great amount of time to analyse, plan, execute, test and maintain an application only designed to satisfy one concrete requirement. In the last several years, we have participated in the development of several customised applications for students with different needs and various types of devices. These applications vary from tools which teach money management, to memory training, motor training, job skills training and online courses, among others. According to our experience, although the applications were successful during the first year of their use, teachers ended up abandoning these tools since they only tackle a specific problem and could not be modified by users without strong technological knowledge. At this point, there is a need

to provide teachers with tools which allow them to take on a more adoptive role in the process of creating educational projects and updating them later on.

Another important phenomenon to consider is the increase in the number of devices involved in the process of creating educational and collaborative activities. In recent years, we have witnessed the constant integration of new technologies such as interactive whiteboards, touch devices and multi-touch surfaces. Personal computers and interactive whiteboards offer a new way through which digital content can be added to education programmes. Nevertheless, these devices are limited since only one student can interact with them at the same time through an input device. This restricts teachers' ability to carry out pure collaborative activities on these devices.

It is also worth mentioning how students perceive the activities once they are presented by teachers, and how they can perform these activities. With traditional interfaces, even if a group of students is behind the screen, only one can control the application through the mouse and a keyboard. This will cause the rest of the students to be bored and to compete for control of the device. In addition, since there are several users behind the screen, there will be times when some of them cannot view the content correctly (Pawar et al., 2007). Also, due to the software used and the devices, they will not take advantage of face-to-face collaboration. This implies that users without control of the device will have problems when trying to express their ideas in an efficient way. On the other hand, it will be quite difficult for the user with the control to manage and remember all the ideas of the group members. This creates an environment in which not all the participants will collaborate. Therefore, traditional interfaces are not enough to perform collaborative activities in the classroom.

Putting the creative power in the hands of teachers requires authoring tools which are capable of allowing them to continuously improve without disruptions in their performance in the creative process. Accordingly, the ease of learning an application is fundamental in order to make the teachers adopt a certain tool. When designing an authoring tool, there are several factors to be taken into account: familiarity, which refers to the fact that knowledge and experience acquired in other scenarios can be applied when interacting with new systems; predictability, which is the user's ability to determine the effect of an action based on what happened in previous actions; and generalisability, which consists of allowing the user to extend the knowledge from one application to another (Dix et al., 2004). Accordingly, the ease of learning can be evaluated by

measuring the performance of teachers when designing educational activities over time. Teachers show different learning curves when using different authoring tools. This curve is influenced by both the interface design and by teachers' skills and previous knowledge. Therefore, design decisions will affect how teachers perceive the tool upon first use, how fast they will acquire competences throughout its use, and how competent they will become if they keep using it. These factors can be observed through the study of the learning curve of each user.

Users can suffer anxiety when challenges outweigh their skills, and they will be bored if their skills are too advanced for the challenges they can tackle with the tool (Csikszentmilhalyi, 1991). This requires attention to be paid to short-term efforts and long-term limitations (Papert, 1980) in order to reduce the anxiety of new users while avoiding boredom in more advanced ones. According to Hackos and Redish (1998), users can be classified into four categories: i) users with little knowledge about the tool; ii) usual users with basic knowledge; iii) advanced users who can perform some technical tasks; and iv) expert users with deep knowledge of the tool. Ideally, users should be able to increase their knowledge over time and move to superior categories. However, there are several barriers which usually hinder this progression. Firstly, if basic tasks are difficult to perform, novice and usual users could abandon the tool. In the same way, a limited functionality could push advanced users away. The approach of using discoverable interfaces which show new functionality as it is required is, in our opinion, one key factor regarding the design. In this way, advanced functionality will be hidden from novice users, but will be accessible to advanced users. Secondly, since not every user has the same needs, users can decide if they would like to stay in the same category. In this case, it is not necessary to show unnecessary functionality.

In addition, several other factors have been identified that prevent teachers from adopting technology completely (Mueller et al., 2008): various comfort levels with technology, doubts about their pedagogical possibilities, lack of training and the time required to understand and use applications (DiSessa, 2000; Hannafin & Hill, 2002). This explains why some teachers reject authoring tools with non-intuitive interfaces, despite the fact that these could offer quality results.

Obtaining an optimal flow during the process of learning a technological application requires consideration of the variety of users and the different needs and

motivations that could be present. Consequently, when a new user-centred system is designed, it is crucial to keep all these variations in mind (Barfield, 1986).

With this in mind, developers should dedicate adequate effort to the design and creation of educational activities for all the devices that currently exist. In addition, the applications should allow teachers with limited technological knowledge to become designers of their own education projects which could be performed on any device. It is also necessary to acknowledge the variability of students' characteristics, which is important to enable customisable parameters so that teachers can change the applications according students' needs and learning goals they want to achieve.

2.2 Integration barriers

The inclusion of technology in education institutions should be implemented by a multidisciplinary team which involves teachers, researchers, technical people, developers and students (Hartley, 2007). Teachers should play a main role in the creation of learning environments where ICT can be used (Lim, 2007). This role consists of tasks such as evaluating the tool, assessing the competences of the students, establishing clear goals, preparing students for the lessons, etc. In order to enable teachers to perform this role effectively, they need support from the other members of the learning environment. In a study about the integration of ICT in classrooms in Singapore, the conditions needed to integrate technology in the classroom and the support provided by schools were analysed (Lim, 2007). Among those conditions, the study included: problem management; technological availability; establishment of learning rules; task management among teachers, assistants and students; and support from school policies.

Existing literature identifies the beliefs and attitudes of teachers as primary barriers to the inclusion of technology in the classroom. Instructors are afraid that technology might have a negative impact in their classrooms (Lindahl & Folkesson, 2012). Educators mention worries such as decreased social interaction, enhanced individualism, and young students possibly becoming addicted to technology (Tsitouridou & Vryzas, 2004). Although most teachers express their rejection of technology integration in the classroom (Fenty & McKendry, 2014), other teachers feel insecure about whether technology should be used in certain education levels, such as childhood education (Joshi et al., 2010).

Some studies show that certain teachers have prejudices that explain the lack of integration of technology in education (Lindahl & Folkesson, 2012). This explanation is centred on the social, cognitive and motor skills of young students, as their educators affirm that these kinds of students are not mature enough to use computers (Ihmeideh, 2010). This aspect is strengthened by the fact that young students do not have sufficient motor skills to correctly manage a computer, although in the last year, and with the appearance of touch devices, this problem has been reduced. However, this fact has not improved technology integration (Blackwell, 2013), which has led other authors to theorise that this situation may be related to educators' perception of technology as a threat to traditional teaching (Lindahl & Folkesson, 2012).

To partially avoid teachers' prejudices towards technology, it is necessary to professionally train the employees of the school which will be in charge of integrating ICT, placing more importance on the digital competences required for the teachers who will use it. Some studies suggest that it is more important to focus on the pedagogy rather than on the technology itself, as well as on the need for innovative teaching styles when working on teachers' digital competences (Guskey, 2002; Law & Chow, 2010; Lovelles, 2003; O' Rourke, 2001). For instance, a good practice could be that teachers could participate in forums throughout their training programmes (Prestridge, 2010). Littlejohn (2002) suggested various strategies to help teachers incorporate new teaching methods using ICT. These strategies are: i) focusing on the results of the training programmes which could be evaluated; ii) facilitating the learning of education theories which make use of ICT; iii) involving academics to assist teachers in planning educational activities; and iv) teaching digital competences.

However, although training programmes are usually planned by academics, the change should originate from teachers; thus, considering teachers' point of view is fundamental (Rodrigues et al., 2003). In this regard, teachers' beliefs about how to use technology to enhance the learning environment, achieve goals and motivate students also play an important role in determining whether and how teachers will use ICT in school (Rodrigues et al., 2003). Moreover, if innovation is not directed towards methods which are currently used in schools, ICT will not be integrated successfully (Fullan et al., 1992).

On the other hand, it should be also noted that teachers need time to learn to use technological tools, create resources and prepare to use ICT in the classroom. Not having enough time to carry out these activities is also one of the most important barriers to

integrating technology in the classroom (Fenty & McKendry, 2014). In the literature, it is recognised that teachers have busy schedules, and that finding time to prepare activities which involve technology is a tough task (Wood et al., 2008). In this regard, a teacher who gives numerous lessons is also impeded from preparing to use this kind of resource (Li, 2006). Along these same lines, the evaluation of students is also a time-consuming task. In many cases, evaluating students is a routine duty; accordingly, some authors have developed tools that are able to create quality questionnaires (Molins-Ruano et al., 2016) and automate the evaluation process (Perez et al., 2005; Rubio-Sánchez, 2014).

In addition, having a technology infrastructure is also a key factor in order to be able to use technology in education. Creating this infrastructure requires taking into consideration the availability of physical devices (computer rooms, server rooms, cables, etc.), software, and human resources which maintain this infrastructure and manage its daily functioning (Lim et al., 2010). In this scenario, the role of ICT coordinators arises; these are people who will be in charge of updating the infrastructure, deciding how ICT will be used and organising training sessions with teachers. Such training will help educators to acquire the confidence to use technology in the classroom, the lack of which is one of the main hindrances to technology integration (Fenty & McKendry, 2014). Through planning, resource management, budgeting and curricular and technological support, these coordinators will guide the teachers towards the implementation of teaching and learning methodologies which take advantage of the use of ICT (Lai et al., 2004).

Hardware is not the only important element for the appropriate integration of technology; access to educational software is also a key factor (Beauchamp, 2004; Nikolopoulou & Gialamas, 2013). In some educational scenarios, teachers affirm that the greatest barrier to technology integration in education is related to the accessibility of quality software (Ihmeide, 2009; Plowman & Stephen, 2005). In a similar manner, Liu and Pange's (2014) work also indicated a lack of appropriate content for the electronic devices which were available to teachers. This study highlighted how difficult it was for teachers to decide which applications could be suitable to achieve the goals planned and facilitate their students' learning.

This aspect derives in part from the lack of support that teachers have in issues related to the use of technology in the classroom. The literature identifies two types of support that teachers need in order to properly incorporate technology in their instruction:

technical support (Nikopolou & Gialamas, 2013) and administrative support (Fenty & McKendry, 2014; Liu & Pange, 2014). Without enough technical support, educators could face problems such as computer breakage or connection failures (Wood et al., 2008). On the other hand, if administrators, government and even parents do not support the use of technology, it will be difficult for teachers to use technology in their classrooms (Nikleia & Despo, 2005).

2.3 Rise of touch devices in education

In recent years, there has been a boom in state-of-the-art technologies that implement a new interaction method which differs from the traditional use of a mouse and a keyboard: touch interaction. These new technologies – typified by smartphones, interactive whiteboards, digital tablets and multi-touch tabletops – allow students to access resources anywhere and anytime, and facilitate the creation of collaborative environments. In the work of Rick et al., (2009) they classified applications designed for education into distributed systems and systems for only one device. An example of a distributed system would be an application which lets users share photos using mobile devices (Kray et al., 2009). On the other hand, applications which only make use of one device could support input from numerous users through multiple input devices (mic, several touch pencils, etc.). Examples of this kind of device include interactive whiteboards and multi-touch tabletops.

With the arrival of these new technologies in education, more possibilities can be offered within classrooms since more than one student can interact with the device and the resources presented on it at the same time. This way, several students can have control over the information and can gain deeper knowledge of the content shown on the device. This control is mainly possible thanks to touch interaction, which allows users to express themselves using natural gestures and creates an environment with better communication and comprehension. This increases collaboration among the individuals, causing them to remain focused on the content (Inkpen et al., 1999; Roldán-Álvarez et al., 2016), have fun (Afrikano et al., 2004), solve problems faster (Inken et al., 1995; Hubber et al., 2016) and learn the importance of social skills (Bricker et al., 1995; Roldán-Álvarez et al., 2014). However, some authors mention that it is necessary to understand what type of interaction can be considered as natural, since to perform certain tasks on a touch interface, you must first learn what gesture you need to use (Dix et al., 2008).

Multi-touch technologies offer a wide range of educational and recreational possibilities (Zuckerman et al., 2005). These technologies are appropriate for students, especially if they are used in order to incorporate key factors in students' development; such factors can include social experiences, thus helping to facilitate the learning environment (Druin et al., 1999). Collaborative learning which arises from this scenario encourages the active exchange of ideas among the different users. This exchange increases the interest of the students and enhances their brain activity (Gokhale, 1995). It has long been known that collaborative teams experience a high level of activity and retain information better than those who work individually (Johnson et al., 1986). By using collaborative software on multi-touch surfaces, students can improve both their cognitive and social skills (Roldán et al., 2014).

Although a gesture-based interface makes it easier to manage the application compared to using a mouse or a keyboard (Tse et al., 2004), the user's arms and hands could block the vision of the other users around the device. In recent years, authors have carried out several studies showing the issues generated by occlusion, which greatly diminish users' performance (Hancock et al., 2004; Inkpen et al., 2006). In the study conducted by Forlines and Balakrishnan (2008), it was discovered that occlusion generates a drop in performance during those tasks where the user needs to interact with the surface. Supporting this study, while Leithinger and Haller (2007) were researching menu positioning on multi-touch tabletops, they discovered that those users who suffered from occlusion were disadvantaged with regard to those who did not. This is because they could not properly visualise the content presented, worsening their awareness of what was happening in the application. They also experienced several issues regarding the interaction with the application, since some elements they needed to interact with were occluded by other users. Along these lines, it has been shown that the arm of a user could occlude 50% of the screen of a 12-inch device (Vogel et al., 2009). In the literature, there are explanations of some techniques which mitigate such occlusion in touch devices. These include, for instance, solutions such as menus that move according to the user's position (Hancock et al., 2004) or menus which move around the device so that they can never be occluded. Ramos and Balakrishnan (2003) used a slide control to reduce the occlusion provoked by the hand of the user on devices controlled by pencils. In an application called Crossy, movements from right to left were used to reduce the occlusion of right-handed users (Apitz et al., 2005). Another study used a pop-up window which

moved the information according to the finger movements of the user (Shen et al., 2005). The Shift application used a similar mechanism, through which the occluded elements 'travelled' to non-occluded areas (Voge et al., 2007).

Occlusion is related to the available space on the device where the application is run. Key factors when working in a multi-touch surface are how this space will be used and how the content will be organised and manipulated. Related studies regarding these factors involve the analysis of the territoriality of collaborative spaces (Scott et al., 2004), the analysis of the impact of the size of multi-touch surfaces (Ryall et al., 2004) and the orientation of the content presented on the device (Kruger et al., 2003), among others.

Managing the available space on the device and organising the elements in an efficient way creates the need for elements to be grouped according to some criteria. For example, Malone et al. (1983) studied how several participants organised their documents on their desktops. Another study examined the way in which users managed files, and whether it was more suitable to pile them up or to organise them in an orderly manner. It was discovered that piling up the elements was more natural, since this required less effort than organising them (Whittaker et al., 2001; Aliakseyeu et al., 2006).

Even with all the evaluations carried out on touch surfaces, not all applications developed for them succeed. This is due to the lack of knowledge about three fundamental characteristics that should be considered when designing educational applications: awareness, action control and transparency.

Awareness entails knowledge of the interactions, emotions and mental states of the rest of the users when interacting with interfaces that require visualisation, touch and gestures (Gutwin et al., 1995). For instance, Marshall et al. (2008) discovered that participants were more aware of their peers' actions when they were simultaneously interacting on a multi-touch tabletop, rather than when one was interacting and the others were watching. Among the most highlighted behaviours of the participants of this study are comments about their actions to avoid clashes by moving out of the way of their peers, or clashing with their peers when they wanted to avoid a certain action. These mechanisms play an important role when discussing collaboration in multi-user interfaces. For instance, in the work of Fleck et al. (2009), students made their actions more visible to the rest of the users by talking and showing their ideas through the multi-touch tabletop at the same time. Similarly, Whalen et al. (2006) showed that the participants in their study were more aware of their peers' actions when they were

performing tasks on a touch surface rather than when interacting with a mouse and a keyboard. There is evidence showing that interactive whiteboards and multi-touch tabletops enhance users' awareness of other devices. Inkpen (1999) showed that participants were more aware of the actions of their peers when using this kind of surface, and when using applications controlled by multiple pencils rather than those which were controlled through a mouse. In addition, Hornecker (2008) compared the use of a mouse with the use of gestures to collaborate in a planning activity, concluding that awareness of interactions was superior when using multi-touch surfaces.

The second characteristic to consider when designing touch surfaces is that they allow more direct control than those which require the use of a mouse or keyboard. Many applications have used this factor to design interactive screens, such as those found in museums and shopping centres (Hornecker, 2008). These devices offer enhanced control of digital content and information. In this regard, Rogers et al. (2009) illustrated the various ways in which users can have control over the device, using the idea of multiple entry points and giving the user the possibility to control different content. For instance, several users can have access to flowers and trees on a multi-touch tabletop or an interactive whiteboard, and could organise them to create their own garden. However, all the issues that may arise from this situation should be considered, since allowing all users to interact at the same time could provoke interaction problems, causing frustration, anger and disappointment (Rogers et al., 2009). For example, one user might organise all the trees and not allow other users to place some trees.

Lastly, transparency covers the comprehension of the task presented on the device, understanding the situation at all times while remembering the interactions that have taken place until arriving at that state. Therefore, transparency is composed of both explicit information (that presented on the device) and implicit information, which refers to the understanding of the background, expectations and rules that arise from the group that is performing the task. One of the main benefits of having a group work around a touch surface is that the information about the task is available for each member of the group. This scenario holds true even for young students who are not able to manage all the content when they work on a surface that is too large for them, since they can see what is happening when someone interacts with the application. However, it is difficult to implement transparency on small devices such as tablets and smartphones. Although

these devices offer a simple way to share information between two people, they are less adequate for larger groups.

2.4 Content creation

In exercise software, teachers usually use authoring tools to create educational and interactive activities for their students. Moreover, teachers can easily share their created content with these applications, getting feedback from other teachers and improving the content provided to the academic community (Su et al., 2005). In this regard, it is necessary to consider that designing educational resources is a prerequisite for facilitating satisfactory learning experiences; thus, we should pay attention to the methodologies and tools teachers require to create this type of content.

Reviewing the most popular evaluation tools and their design paradigms, we found that interaction through menus is quite extensive (Venugopal et al., 2005). Table 1 shows a summary of authoring tools with specifications regarding the type of interaction with the tool's user interface, the type of activities that can be designed and whether the tool supports the creation of collaborative activities.

A prototypical example is JClic (XTec – Educational Telematic Network, 2010), which allows the creation of different types of educational activities such as puzzles, associations, text activities, and crosswords. Activities are grouped into projects. The interface is based on a menu with four main tabs: 'Project', for defining general features; 'Media Library', where the teacher must provide all the multimedia content such as images, audio or video; 'Activities', where the teacher selects the next activity to be created or updates those previously defined; and 'Sequences', where the order to accomplish the activities is specified. A different set of options is then displayed, depending on the type of activity selected. Hot Potatoes is another project with a similar approach (Half-Baked Software Inc. and University of Victoria Humanities Computing and Media Centre, 2013). This tool requires previous knowledge related to web design and the use of image manipulation programs (e.g. GIMP, Photoshop or Paint) if teachers want to include images of different sizes.

Another tool, Smart Notebook (SMART, 2013), uses an alternative approach in which activities are designed by dragging and dropping visual elements, or by directly painting on the screen. However, the activity creation is not consistent across different types of activities, since each type must be selected from a menu and different options

appear for each element to configure the corresponding activity. This forces users to learn new concepts each time they want to design a new type of activity; this negatively impacts the learning curve, causing the user to spend more time on mastering the tool. Along the same lines of dragging and dropping, the Mouse Mischief add-on (Morajevi et al., 2008) harnesses the potential of the PowerPoint interaction paradigm to turn it into a simple but powerful authoring tool. However, it has a small variety of activities.

Table 1. Authoring tools

Authoring tool	Interaction style	Educational activity types
ARIES	Hierarchical object paradigm / Menu	Augmented reality simulations
Bookbuilder	Frame paradigm / Menu	Creating courses
Cognitor	Tagging paradigm / Menu	Creating courses
DEDOS-Editor	Card-based paradigm / Drag and drop	Simple and multiple-choice, pair-matching, and mathematical activities
Hot Potatoes	Hypermedia linkage paradigm / Menu	Simple and multiple-choice, pair-matching, crosswords, order words, fill in the gaps
JClic	Hypermedia linkage paradigm / Menu	Simple and multiple-choice, pair-matching, exploration, puzzles, fill in the gaps, memory games, crosswords, alphabet soup, identifying sounds
JelSim Toolkit	Frame paradigm / Menu	Physics and math simulations Simple and multiple-choice
LAMS	Icon-based paradigm / Drag and drop	Simple and multiple-choice, text answers
Microsoft LCDS	Icon-based paradigm / Menu	Simple and multiple-choice, essay
Mouse Mischief	Icon-based paradigm / Menu and drag and drop	Simple and multiple-choice, fill in the gaps
Quandary	Hypermedia-linkage paradigm / Menu	Creating courses, simple and multiple-choice
REDEEM	Frame paradigm / Menu	Simple and multiple-choice, creating courses

Smart Notebook	Card-based paradigm / Drag and drop	Simple and multiple-choice, pair-matching, text answer, identifying sounds, order words
Xerte	Scripting paradigm / Menu	Creating courses, simple and multiple-choice, pair-matching, fill in the gaps

Exercise authoring functionality can also be found embedded in tools allowing teachers to create course-based learning environments, where activities are designed to be executed as part of a course. A fairly representative example of this class of tools is Microsoft LCDS (Microsoft Learning, 2013), which helps teachers to create learning environments that will be executed as computer-based training applications by specifying their own pedagogical principles. Other projects that focus on authoring courses are Xerte (University of Nottingham, 2008), REDEEM (Ainsworth & Grimshaw, 2004), Bookbuilder (CAST, 2006), Cognitor (Neto et al., 2006) and Quandary (Half Baked Software, 2003). Such applications are based on configuring a course across multiple menus and forms. In these tools, activities are organised according to a course structure rather than a project structure. Therefore, the output combines educational material with activities in which content creation occupies a significant portion of the design process. Interactive activities are designed in a similar way to JClic or Hot Potatoes. However, being more ambitious in scope, they tend to focus on professional content creators rather than on teachers with time constraints and a basic computer background in most cases. This impedes the learnability of the tool, making help mechanisms and virtual assistants critical for the tool's adoption. For instance, REDEEM assists in the creation of a learning environment by guiding the user through a question and answer process. This allows teachers to design complex tasks with simple actions, although it may be a time-consuming process. Likewise, LAMS also facilitates the definition of course structures by using direct manipulation, but as it is oriented to multimedia content creation, activity types are limited to questions and answers (LAMS International, 2004).

One relevant aspect that is usually overlooked when analysing learnability is the variation in teachers' computer skills. An interesting approach that accounts for these differences is JelSIM toolkit (Thomas and Milligan, 2004), a software suite for easily creating and customising physics and math simulations. The toolkit shows different interfaces according to the user's computer proficiency. To create identical simulations,

a Java programmer has access to a programming interface, whereas a teacher without proper programming skills can use a graph-based graphical interface to simplify the creation and simulation process. The variety of user interfaces is very interesting from the point of view of learnability, although it makes it more complicated to jump from one level of expertise to the next, and the implementation might benefit from including an intermediate proficiency level.

Apart from the interaction mechanism, another issue is that few tools offer the possibility to create activities that multiple students can solve at the same time and on the same device. It is important to keep in mind the wide range of devices that teachers may have in their classrooms, and through which students could simultaneously interact and collaborate. This implies that we should take into consideration the issues that may arise from using each device while performing activities; collaboration, simultaneity and physicality therefore become key factors during the design process. Few of these tools pay attention to these factors. For example, SMART Notebook considers some of them, but activities created by this application are intended to be performed by a single student. This is despite the fact that more than one student can interact with the digital blackboard to carry out the activity. If teachers want students to perform the same activity in different workspaces, they should replicate the activity for each student.

2.5 Learning experiments

ICT can support different learning approaches such as inquiry-based, problem-based, self-regulated or collaborative, among others (Niederhauser and Stoddart, 2001). Literature sees ICT as a master key to facilitate technology-enhanced learning environments which are centred on students (Hannafin & Land, 1997). In this regard, current research focuses on locating those elements which support the inclusion of ICT in classrooms based on the education level (Cox, 2008). This section presents several technology uses in learning experiments from several levels (childhood education, primary education and special education), commenting on particularities of each educational level and the benefits offered by technology with respect to students' learning.

2.5.1 Childhood education

Studies about the use of ICT in childhood education show a landscape full of ups and downs and uncertainty (Mueller et al., 2008). These complicate the integration of technology in this educational stage (Siraj-Blatchford et al., 2006). Until now, little attention has been paid to the use of ICT in childhood education (Tu & Kuo, 2012). McManis and Gunnewig (2012) affirmed that research regarding new hardware and software for use by young students has a long way to go, since even now it is difficult to find empirical studies which show the benefits of using technology in childhood education. For instance, Terreni (2010) highlighted that there is little research regarding the use of interactive whiteboards at this educational stage. This is also true for digital tablets, as several evaluations of teachers' acceptance of these devices can be found, but little is known about their deployment in classrooms (Plumb et al., 2013).

Nevertheless, many teachers believe that the use of technological resources can provide extra opportunities that will allow them to organise attractive activities for the students which are compatible with traditional teaching methods (Blackwell et al., 2014). In the literature, some studies show some of the benefits of using digital content in childhood education, such as: access to motivational applications with dynamic and interactive presentations, options to implement individual teaching and learning processes, and the possibility to give immediate feedback on students' interactions (Lin, 2012; Lee et al., 2008; Gimbert et al., 2004).

The particularity of this educational stage means that some factors must be considered which are not encountered at other educational levels. Due to the students' age, their physical and communication capabilities are less developed, which makes them less able to work independently. The use of computers at this age presents certain physical challenges provoked by the students' lack of advanced motor skills. For example, using a mouse is troublesome for them (Donker et al., 2007). Moreover, tasks such as locating some functionality on the screen or understanding written messages pose cognitive issues (Wood et al., 2004). In this scenario, we find that personal computers are the most extensively used devices in educational institutions (Kirkup et al., 2005). These devices use what is known as a WIMP user interface (windows, icon, menus and pointers) in which the user input is given through a mouse and a keyboard, which is not appropriate for young students. However, touch devices allow interaction through natural and direct gestures, making their use possible at early ages (Norman et al., 2010). Accordingly, it is

believed that touch devices are becoming the main learning vehicle in the educational environment, and childhood institutions are gradually including these devices (McManis & Gunnewig, 2012).

In the literature, the suitability of touch devices for use in childhood education has also been highlighted (Beschorner et al., 2013), although there are not enough studies which discuss the benefits (Plumb et al., 2012). Digital tablets allow direct manipulation of the interface, and are intuitive to learn since they do not require a mouse; this makes them cognitively simpler than computers (Geist et al., 2012). For instance, in a study carried out by Cohen (2011), two-year-old students used tablets to perform pair-matching and math activities independently.

In this area, it is possible to find some studies performed in childhood education, such as that carried out by Cuban (2011). In his work, he showed how students only used computers during their free time, as a leisure activity and not as part of their learning. Unlike this study, in the work of Miller et al. (1994) the teacher combined technology with traditional learning methods to teach students to read and write. The study of Gimbert et al. (2004) demonstrated how teachers made efforts to include technology in the classroom, with the goal of adapting the activities they usually did to the technology available. Again, a central point was that it was fundamental to understand how teachers want to use digital resources and add them into their teaching process (Prieto et al., 2011).

Regarding the devices used, examples can be also found in the literature about how the use of digital tablets has a positive impact on childhood students. For instance, in Chmiliar's work, students had to play with educational applications for 6 weeks (Chmiliar, 2014). The students learned to interact with the tablet computer without problems in approximately 20 minutes, and the applications were entertaining and captured their attention. After this experiment, the students were able to use tablets autonomously to learn. A second example is that of Beschorner and Hutchison (2013), who carried out a qualitative study where students aged 4 and 5 played with digital tablets. This experiment highlighted that even if students worked individually, they usually interacted with other peers around them to solve problems collaboratively.

With respect to interactive whiteboards, an analysis of the literature shows that learning to use these devices encourages students to tackle new challenges and increases their participation, motivation and cooperation (Goodreau, 2013). Interactive whiteboards also help with reading comprehension, vocabulary and communication (Hansen, 2008).

Given that the inclusion of these devices in education came before digital tablets, more educational experiments have been performed with them. For example, Morgan (2010) researched learning among students from 3 to 7 years old in classrooms equipped with interactive whiteboards. The findings revealed that teachers positively valued the ability of interactive whiteboards to promote interactive and fun experiences for students' learning, but in practice, their use was limited due to the lack of digital competences, the lack of technical support, and difficulties when designing or choosing appropriate digital resources. Gill and Islam (2011) found that creating educational experiences of shared reading was easier when using interactive whiteboards, since these facilitate the recording of the lesson, which allows teachers to save it, share it and reuse it. In conclusion, the studies indicate that the use of interactive whiteboards in childhood education enhances the students' engagement and motivation, while also increasing students' attention span (Jones et al., 2011).

Lastly, some studies have examined childhood education students' use of multi-touch tabletops. For instance, in Marco et al.'s (2009) work, several students from 3 to 4 years old used tangibles and a multi-touch tabletop to perform farm tasks such as feeding the animals or matching babies to their mothers. This experiment showed that students accepted this new interaction method, and also learned while having fun.

2.5.2 Primary education

The use of ICT for teaching is a main goal for primary education schools (Vanderlinde et al., 2009). For many decades, several authors have studied the potential of technology at this educational stage, pointing out the capabilities of computers to support and even improve teaching and learning processes in primary education classrooms (Cox et al., 2004). Other critical voices raise questions regarding the efficiency of the use of technology in classrooms (Cuban et al., 2001). Reviewing the literature, it can be observed that in primary education teachers usually make use of technology for two different purposes. First, to perform administrative tasks such as managing students, evaluation, preparing templates or following students' progress. Second, teachers use technology for demonstrations, practical cases, instruction and differentiation (van Braak et al., 2004).

In primary education schools, children are encouraged to build knowledge and to understand concepts through research, questions and discussions. This constructivist

theory can make use of ICT to achieve pedagogical goals. For instance, Yang's work described a case study in which web resources were integrated into a history project with the collaboration of elderly people (Yang, 2009). This project provided a great opportunity for the students to use their problem-solving skills and improve their historical thinking. Yang also highlighted that the participants showed satisfaction when they finished the projects, and they displayed a greater empathy with elderly people. In other studies, games have been used to enhance learning. For instance, Lim carried out a study at a primary education school in Singapore, working on the concept of globalisation through a game called Atlantis (Lim, 2008). Students were the protagonists of this game, living on the fictional island of Atlantis. In this game, they had to face ecological, social and cultural issues that arose due to the governor's seeking prosperity and modernisation of the city. Through Atlantis, students were involved in English, math and science activities, solving problems individually or collaboratively. This kind of game had a positive impact on the learning, motivation and social engagement of the students.

Interactive whiteboards facilitate modelling, explanation, demonstration and discussion within the classroom. Lewin wrote about the process of changing pedagogical practices, which is necessary in order to effectively use interactive whiteboards in the classroom (Lewin et al., 2008). The results of this study showed that students who were exposed to the interactive whiteboard increased their literacy skills. Moreover, this study pointed out that the adoption of technology in the institution was not carried out individually by each teacher. Instead, it was a group task in which every member of the school team worked on the integration of interactive whiteboards in their classrooms, sharing ideas and practices amongst each other. Dillenbourg and Evans (2011) suggested that interactive whiteboards could be used to enhance face-to-face collaboration. For instance, small groups of students could gather around this device to discuss or build conceptual maps, which can support their reading comprehension and their writing plan. In the study of Sad and Ozhan (2012), they researched primary students' opinions about the use of interactive whiteboards in their classrooms, evaluating the quality of the lessons and defining the pros and cons of the whiteboards' use. The results indicated that the students appreciated the ease of use of interactive whiteboards, the better presentation of the content in comparison to a personal computer, ease of access to multimedia content and improved learning. From a pedagogical point of view, the interactive whiteboard enhanced students' learning due to characteristics such as visualisation and

contextualisation of the content, effective presentation of the content, and motivation and participation of the students. However, this experiment also discovered that although interactivity is one of the main features of interactive whiteboards, this was the least referenced attribute by the participants.

Since ICT is constantly evolving, the opportunities for teaching and learning are evolving as well. The use of personal computers and the Internet does not have to occur in a fixed place, since the appearance of mobile technology facilitates the use of technology and access to the Internet wherever and whenever it is desired. One interesting development of ICT in primary education has been the introduction of digital tablets. Mobile devices are slowly being included in primary education classrooms, and both teachers and students have found several ways of using them to achieve a wide range of goals apart from those included in schools' curricula (Pegrum et al., 2013).

The literature contains several examples of studies where digital tablets were used to achieve math skills. For instance, Tangram, a tool to teach geometry through puzzle building, was used to help students to learn geometric concepts through a collaborative learning environment using digital tablets (Lin et al., 2011). Students recorded an improvement in their spatial and reasoning skills. Face-to-face collaboration was enhanced, and the communication among the students increased their critical thinking, confidence and attitude towards learning. Moreover, teachers saw that it was easy to summarise and explain geometrical concepts through puzzles. Other experiments focus on general learning with digital tablets as tools which allow the student to access complementary information to that given by the teacher in the classroom, or to access the definitions of concepts they do not understand (Henderson & Yeow, 2012).

2.5.3 Special needs education

Last but not least, ICT can be particularly relevant for people with special needs when performing routine activities (Martin et al., 2013; Llinás et al., 2009) and pursuing education and labour integration (Roldán-Álvarez et al., 2016). In the learning process, the use of technology in the classroom helps people with special needs to share information and acquire independence (Seegers, 2001). Technology can improve their confidence and motivation since it offers learning without mistakes, custom assistance and adaptability to to students' learning (Duffy et al., 1994). In this context, mobile and touch devices have made touch technology accessible for this population. The simplicity

and benefits of touch interaction, combined with the portability that mobile devices offer, have reduced the existing barriers to interaction with electronic devices (Hourcade et al., 2013). Nowadays numerous technological efforts have been made to allow people with special needs to use technology without any problems. In this endeavour, alternate texts and screen readers have been developed for people with visual disabilities, alternate texts for audio messages for people with hearing disabilities, and graphical user interfaces with larger elements and that can be interacted with in different ways by people with motor disabilities. Due to the great variability in users' features in this regard, there are not enough studies in the area of intellectual disabilities (ID) and Autism Spectrum Disorder (ASD); nevertheless, as time goes on more attention is being paid to this population, thus increasing the number of related studies that can be found in the literature.

Although students with ID and ASD have different characteristics, there are some common ones among them, such as issues when interpreting information, easily becoming distracted and sometimes having problems communicating. All these factors should be considered when developing applications for such users (Adamson, 2010). In this context, several studies confirm the interest sparked by touch technologies (WATI, 1997; Whalen et al., 2006; Sampath et al., 2012).

This interest has led developers to design many applications to help students with special needs, making it difficult for teachers to choose which is most appropriate to achieve their goals (Abinali et al., 2009). This issue becomes worse due to the lack of information regarding the use of methodologies to design educational applications for this group. Although interaction can be simple and accessible, the question remains: What kind of applications are the most appropriate in order for students with special needs to improve in the areas where they have the most problems? In some cases, teachers do not achieve their pedagogical goals due to the fact that application does not offer appropriate content (Lloyd et al., 2006). For this reason, it is not only important that the application is usable and accessible, but it is also essential that the content can be adapted to the users. In the literature, some examples can be found regarding how technology can positively impact students with special needs. In general, people with special needs learn social and job skills which will allow them to integrate into current society (Gilson et al., 2016). Ortega-Tudela et al. (2006) carried out a comparative study in which students with ID completed math activities with technology and using traditional methods. Students who used technology performed better than those who did the activities through traditional

methods. Moreover, the study highlighted how offering task sequencing and content presentation in a more visual way influenced the participants' performance. Other studies include those presented by Muro et al. (2012) and Lingnau et al. (2012), in which touch devices were used to enhance students' learning. In the first study, the main goal was to improve literacy skills while observing students' motivation throughout the study. In the second, researchers focused on enhancing communication through puzzle building. In both cases, the number of interactions among the participants increased throughout the study, and the students collaborated more with their peers as they became familiar with the technology. There are other works in the literature in which touch devices are complemented with tangibles as a means of interacting with the device. For instance, in Bonillo et al.'s (2016) study, students with developmental disorders benefitted from this kind of interaction to train their psychomotor and communication skills, and to control hyperactivity. The results of this study showed that instructors were satisfied with the activities designed, although they indicated the need for a system which allowed them to evaluate students' results.

The literature includes some specific examples of studies which intended to enhance the communication skills of people with special needs using digital tablets. For instance, Edler et al. (2014) presented a study in which they aimed to analyse the attitudes of people with ID and how they solved certain challenges using iPads. The participants were active and motivated thanks to the use of these devices, and they quickly acquired total independence to perform the required tasks. Regarding labour training, in the study of Roldán-Álvarez et al. (2016), students with ID worked on the acquisition of job skills throughout the creation of videos using iPads. In this study, it was again noted that the use of these devices motivated the students, that the students learned to use the devices autonomously, and that they successfully acquired knowledge about job-related skills.

At the same time, recent years have seen an increase in the number of studies oriented towards using ICT in the educational development of students with ASD. These studies show that the use of technology and appropriate software motivates students and helps to capture their attention (Gal et al., 2009; Hourcade et al., 2012). Moreover, touch devices are more appropriate for people with these disorders, since they can interact with the application in a more direct way than with traditional interfaces and do not need peripherals such as a mouse or a keyboard. This allows them to focus on the activity and not on the peripherals required to perform it, thus making the process of learning more

effective. Nowadays, some of the skills that people with ASD most frequently train with the use of technology are communication, recognition of emotions, time management, social skills and collaborative learning (Hourcade et al., 2013).

Some examples regarding the use of touch technology by ASD students can be found in the literature. For instance, Hourcade et al. (2012) developed an application which allows students to collaborate to paint, create music, solve puzzles or recognise emotions. This study highlighted that technology helped teachers to get to know their students better, understanding how their minds work and how they interact with their environment. Moreover, technology enables the creation of secure spaces where the student can explore and interact without being observed or judged. The work of Gal et al. (2009) focused on enhancing collaboration and social interaction. For this purpose, participants had to collaboratively build a story while simultaneously interacting to face certain situations using StoryTable, an application which supports the creation and recording of narrations in virtual environments. In this study, an increase in social interaction was observed among the participants, along with enhanced emotional expression. The interest in improving social interaction of people with ASD has been strongly transferred to the academic community, and that is why a number of applications have been developed with the intention of enhancing face-to-face collaboration, one of the greatest issues for people with ASD. For instance, a group from MIT implemented a mobile app with the goal of helping ASD people to recognise emotions in face-to-face situations (Madsen et al., 2009). Moreover, there are applications that allow users to choose from several icons and drawings, which are translated to voice to help users express their emotions (Sampath et al., 2012). Virtual agents also exist, enabling children with ASD can practice face-to-face communication and even interact with each other through these agents (Frauenberger et al., 2012; Porayska-Pomsta et al., 2012; Tartaro et al., 2016).

This chapter has shown that ICT offers new opportunities for education, such as the possibility to interact directly and naturally with the hands, and the creation of digital content by teachers. In this regard, some members of the education sector are still doubtful about the benefits of ICT in education, and those who want to integrate it in their classrooms must overcome certain challenges without the appropriate support. The wide range of educational software available on the market makes it difficult for teachers to choose which application is appropriate for their students. Furthermore, such applications

should be compatible with the devices available at the educational institution. With the goal of tackling these issues, an authoring tool called DEDOS-Editor has been developed in this work, which allows the creation of card-based educational activities. In addition, two players, DEDOS-Player and DEDOS-Web, have also been developed, which enable users to carry out these activities on a wide range of devices, such as personal computers, interactive whiteboards, digital tablets and multi-touch tabletops. In this work, special attention has been paid to how touch technology could be used in education, since the interaction offered by touch devices provides access to technology for young students and special needs students.

CHAPTER 3: DEDOS-EDITOR

This chapter presents DEDOS-Editor, an authoring tool which allows the creation of card-based educational activities that can be performed on a wide range of devices (personal computers, interactive whiteboards, tablet computers and multi-touch tabletops). Before explaining the details of this tool, the design choices taken before starting the development process are described. Firstly, a study was carried out with the main goal of identifying the most popular activities designed when using an authoring tool. Based on this and other motivations, the activities to be implemented with this tool were chosen. The next step was to define the design principles to be taken into account with respect to the authoring tools described in the previous chapter, with the main goal of developing a usable tool. DEDOS-Editor was then developed, and lastly, the data model of the activities was defined so that DEDOS-Editor could interoperate with DEDOS-Player, DEDOS-Web or any other tool which might be used to execute DEDOS educational activities. This data model was called D2XML.

3.1 Finding the most popular activities

One of the challenges to maintaining an optimal learning curve entails finding a consistent interaction metaphor which facilitates the reuse of the knowledge acquired while interacting with the tool. Within this thesis, we aimed to identify the most popular activities designed by teachers so that we could study their similar features and implement a consistent creation metaphor for them. Firstly, after reviewing the tools in Table 1 and classifying the type of activities they support, it was determined that all of the tools allow the creation of multiple-choice activities except for ARIES, which was designed to build augmented reality systems. Multiple-choice activities consist of choosing one or more options among the possible answers to a question. Pair-matching activities are the next most popular, supported by five of these tools, followed by fill in the gap activities. Although less common, other activities can be found as well, such as word ordering, puzzles, crosswords and memory games.

To complement the data gathered when reviewing the literature, we carried out a study in which we analysed the final projects of students from the subject 'ICT in Education' within the Childhood Education and Primary Education degrees. The main goal of this subject was to teach the students the variety of technological resources they could use in the classroom, with the core of the subject being the creation of educational

activities with tools such as JClic-Author and Hot Potatoes. Throughout the course, the students had to design a didactic unit using one of these tools. Apart from this, there were no other constraints regarding the type of activities the students could design, and therefore they could choose whatever activity they deemed appropriate to achieve their learning goals.

In this study, 37 educational projects were analysed: 24 projects of students from Childhood Education and 13 projects of students from Primary Education, with a total of 234 and 102 activities, respectively. There were no limitations to the number of activities the students could include in their projects, so the number of activities in each project could vary. Through the analysis, 20 types of activities were identified and grouped into five categories: information (activities to give information to the students), exploration (activities where students click elements to discover something), multiple-choice, pair-matching and other (including 16 types of activities that were less commonly used). The most popular activity types were multiple-choice activities (32% in Childhood Education projects and 41% in Primary Education projects) and pair-matching activities (30% and 14%, respectively).

To confirm whether this scenario was the same in the projects designed by in-service teachers, we randomly selected 189 projects from JClic's[1] official web repository. In this sample, we selected 84 projects from a total of 284 teachers of Childhood Education, and 105 projects from a total of 928 teachers of Primary Education, identifying 14 types of activities. The size of each sample (n) was calculated as follows:

$$n = (N \cdot \sigma^2 \cdot Z^2) / [(N - 1) \cdot ME^2 + (\sigma^2 \cdot Z^2)]$$

Where N is the size of the sample, σ is the standard deviation, Z is the z-score associated with the confidence level and ME is the margin of error. N was the total number of projects: 284 and 928 for each education level. Since σ was unknown, we assumed a value of 0.5. Z was 1.96, calculated with a confidence level of 95%. Finally, the margin error chosen was 9%.

Once all the data was processed, it was observed that the most popular activities were pair-matching activities (33% in Childhood Education and 26% in Primary Education), followed closely by multiple-choice activities (26% and 21%, respectively). This last analysis detected a significant increase in information and exploration activities.

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[1] http://clic.xtec.cat/es/act/

Combining all the data gathered, it was determined that the students from education degrees preferred multiple-choice, pair-matching, information and exploration activities, which comprised 70% of the projects in Childhood Education and 60% of the projects in Primary Education. In a similar trend, these activities made up 78% and 66% of the activities analysed in the projects from JClic's repository, respectively. For this reason, DEDOS-Editor was first developed by taking into account multiple-choice and pair-matching activities, facilitating a similar design metaphor for their design. The aim of doing so was to provide teachers with a tool that allows them to design the most popular activities in an effortless way.

3.2 Type of activities

Based on the previous study, the activities most often chosen by teachers when using authoring tools were identified: multiple-choice and pair-matching. In the end, the decision was made to complement these activities with addition and connect the dots activities. On one hand, addition activities were included in order to add a mathematical component to the activities available with DEDOS-Editor. This allows the design of activities to train counting skills. On the other hand, connect the dots activities were included at the request of the Fundación Down Madrid, which saw this type of activity as useful for students with disabilities to train motor skills on multi-touch tabletops.

In total, this authoring tool allows the design of four types of activities: multiple-choice, pair-matching, addition and connect the dots. In multiple-choice activities, users choose among various answers according to the question given. In pair-matching activities, users associate the concepts presented in the activity. In connect the dots activities, users follow a path established by the activity creator. Lastly, in addition activities, users drag and drop elements that represent a numeric value until these add up to a determined value.

3.3 Design principles and graphical user interface

Taking into consideration the details of the previous chapter and the most interesting activities to include in the authoring tool, we implemented a card-based design metaphor to encompass the design principles for creating educational activities: direct manipulation and consistency. In order to design a good graphical user interface, it is necessary to bear in mind that the time required by the user to learn how to use the

application should not be too lengthy. The way of interacting should be easy to remember and should reduce the number of mistakes the user can make, the tasks should be performed in an efficient way, and the graphical user interface should be easy to understand. Future users of this tool are people with basic knowledge about the use of computers, focused on the use of text processors and presentation tools. With the main goal of providing a familiar interface for this kind of user, we have based the DEDOS-Editor graphical user interface on Microsoft PowerPoint, since most of the teachers know this program and use it on a regular basis.

Each activity is based on a card game in which the teacher decides the content of the cards and the goals to be achieved. The cards are virtual items with a strong likeness to their physical counterparts, and are used by dragging and dropping them. For instance, the activity is designed by dragging cards from the toolbar and dropping them onto the board. At all times, the application gives feedback on the interaction in a visual way; this helps the user to understand the creation process and progress, thus reducing the effort needed to advance with the tool. Figure 2 shows the graphical user interface of DEDOS-Editor with a multiple-choice activity.
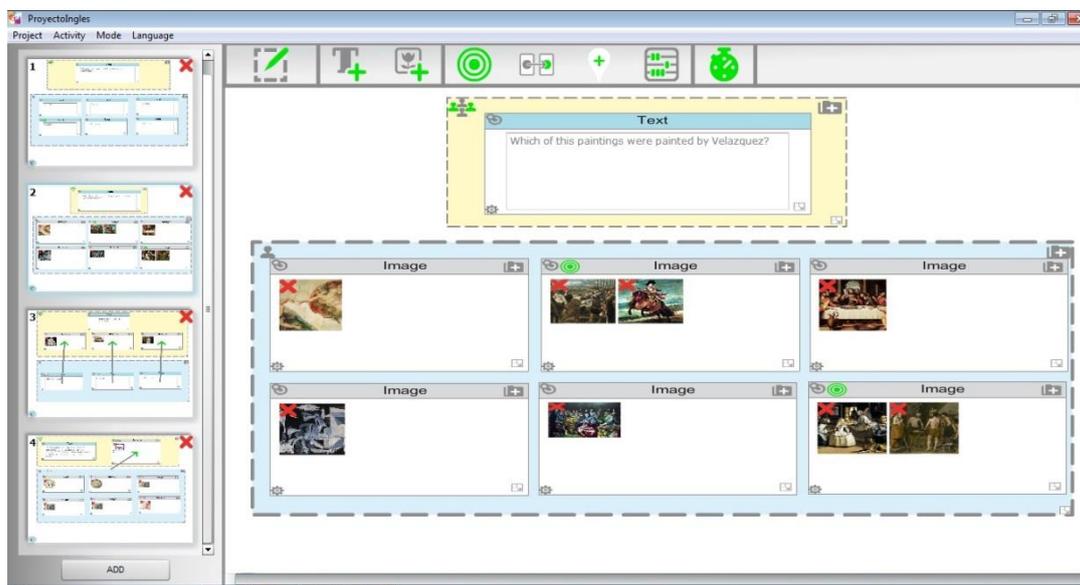
Figure 2. DEDOS-Editor Graphical user interface, Main view

Activities that can usually be designed through DEDOS-Editor are consistently defined through their analogy with cards and goals. In all the activities, the corresponding goals are used in a similar way. On the one hand, in multiple-choice activities this is done by choosing which cards are part of the right answer by dragging and dropping the multiple-choice goal onto the card/s. On the other hand, in pair-matching activities the

cards are paired through arrows which are created by dragging and dropping the pair-matching goal onto one card and connecting the arrow to another card. These cards are placed in areas which act as card and goal containers. Addition activities are designed in the same way as pair-matching activities, with the only difference being that in these activities an addition goal is added in order to define the value that the user shall reach. Lastly, connect the dots activities are created with an area where users drag and drop goals to draw the path. This metaphor and these elements are enough to include different activities, such as crosswords. Through reusing concepts, elements and operations, a consistency is provided that facilitates the creation of new types of activities while enhancing the user's confidence in mastering the use of the tool; this avoids conceptual jumps and strengthens the philosophy of 'the more I know, the easier it will be to learn what I do not' (Roldán-Álvarez et al., 2016).

Taking into account user diversity (Hackos et al., 1998), DEDOS-Editor hides advanced configurations from new users instead of showing the full potential of the tool immediately. Advanced options are hidden behind the cards, which can be flipped over to reveal these options. As teachers become experienced with the tool, they will end up discovering these options that will help them to configure the design of the activities more precisely. This strategy avoids overloading new users and smooths the process of discovering functionality, which allows the acquisition of competences to occur in a less abrupt manner. Moreover, there are some logic limitations that prevent users from making mistakes due to a lack of knowledge about the tools. For instance, cards will be blocked in the toolbar until the user places an area on the editing board, and the goals will be blocked until cards are placed.

The user interface of DEDOS-Editor has four main elements (see Figure 3):

- The editing area (1) is where the user must drag and drop the elements needed to create the activity. When the user starts designing the first activity of the project, this area will show a message to indicate the first steps to follow to start designing the activity.

- The activity panel (2) allows the user to navigate through the designed activities by clicking the corresponding thumbnail (3) and visualising the activity in the editing area (1). In this panel, users can find a button that allows them to add a new activity.

- The toolbar (5) shows the elements that can be added into the activity. These elements are grouped into three groups: areas (6), which allow grouping and organising cards;

cards (text (7) and images (8)), which are the main pillars to build activities; and goals (multiple-choice (9), pair-matching (10), connect the dots (11) and addition (12)). There is also a time objective (13), which specifies whether the activity should be solved within a certain period of time. All of these elements are manipulated by dragging and dropping them into the editing area, as if they were physical items.

- The bin (14) allows the user to drag and drop elements into it to delete them from the editing area.
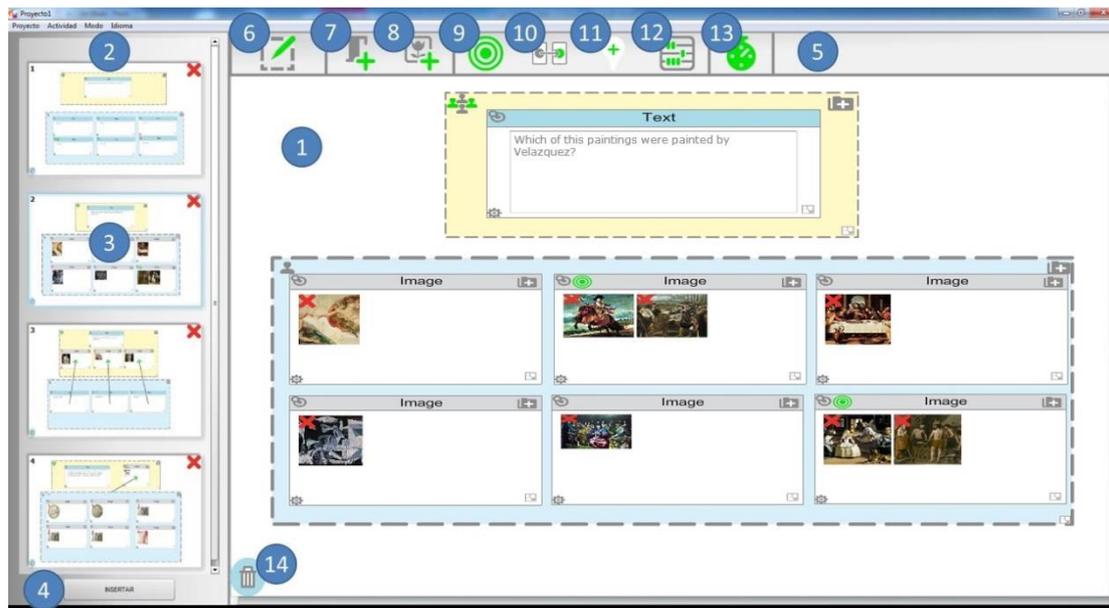
Figure 3. DEDOS-Editor, Detailed graphical user interface

Moreover, each of these elements show tooltips when the mouse cursor is placed over them, providing information about their functionality. Apart from organising cards through the use of areas, the user can define two types of areas by clicking the icon in the top left corner of the area. By doing so, users can define game areas and player areas, which affect the way in which the contents in this area will be shown to the students when solving the activities. The game areas are placed in the middle of the device where the students will solve the activities. However, the player areas represent the individual workspaces of each student, and will be duplicated dynamically depending on the number of students who will solve the activities.

3.4 Activity design

This section presents the four types of activities that users can design with DEDOS-Editor: multiple-choice, pair-matching, addition and connect the dots.

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3.4.1 Multiple-choice

To design a multiple-choice activity, the user must drag and drop at least one player area into the editing area in order to place cards on it and start building the activity. Figure 4 shows an example of a player area with a card which contains the question and the cards that will be part of the possible solutions. The user could also place the card with the question in a game area. In this case, the card would appear in the middle of the screen and would not be duplicated for each player.
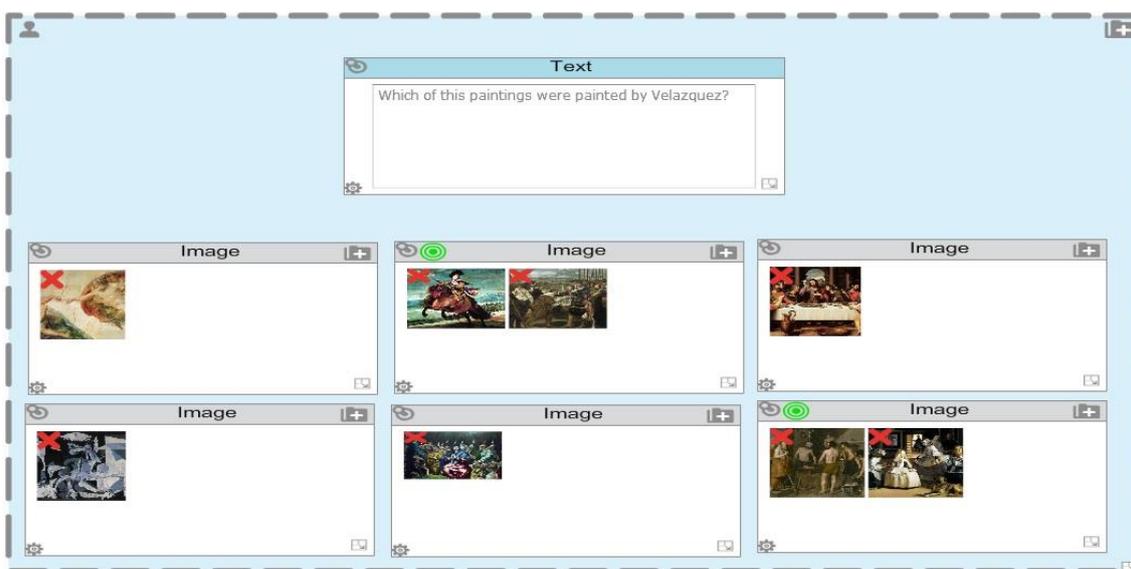
Figure 4. DEDOS-Editor, Multiple-choice activity

To add cards into the area, the first step is to drag and drop the area type from the toolbar to the area the user has just placed. In our example, we have used a text card for the question and six image cards which are part of the possible answers. If the default size of the area or the cards is not adequate, this can be resized by clicking and dragging the bottom right corner icon until the desired size is obtained.

Once the cards are placed, the user can include content in them. If the user wants to add text to a text card, he/she only needs to type the text in the textbox. If images are to be added into an image card, the user must click the icon located in the top right corner of the card to open a dialog box, which lets the user select an image. It is possible to add more than one image to each card so that, when students solve the activity, the application would randomly show one of the added images. This way, each player area could contain different content, which will help to prevent students from copying from each other.

All the cards have an option to let users decide whether the card can be moved when solving the activity. This option is represented with an icon of a pushpin, which is located in the top left corner of the card. This option has been enabled so that teachers can decide whether or not the cards can be moved, which is particularly useful in collaborative activities. In our example, this option has been activated for every card so that students cannot move them, since this is not an activity where students need to drag and drop cards. Moreover, cards have advanced options which are hidden on their reverse sides. To access these options, the user must click the gear that is placed at the bottom left corner of the card. Once clicked, the card flips over to show three tabs. In the first tab, the user can choose whether the card can be i) selectable, if the card can be clicked; ii) rotatable, if the card can be rotated; and iii) resizable, if the card can be resized. Moreover, the user can add feedback to the card which will be shown if the user clicks this card and it is not a correct answer. Finally, it is possible to add a numeric value to the card; this is an option that will be used to design an addition activity, which is detailed in the following sections.

3.4.2 Pair-matching

Figure 5 shows an example of a pair-matching activity whose goal is to pair each sculptor with his sculpture. As in multiple-choice activities, the first step is to add the areas. In this example, there is a game area where the instructions for the activity and three card images with a sculpture will be placed, and a player area with three text cards and the name of a sculpture in each one. This way, the students will have the text cards with the sculptors in their own workspace, and in the middle there will be a game area with the instructions for the activity and the image cards with the sculptures. This game area will be common for all the students, and each of them will have to drag and drop the cards with the sculptors' names to the corresponding sculptures in the game area. If the activities are performed on an individual device such as a tablet, both areas will be shown on the screen, as if the user has used two player areas.

To pair each sculptor with the corresponding sculpture, the user must drag the pair-matching goal from the toolbar and drop it on the origin of each pair (text cards with the sculptors' names), moving the head of the arrow to the image card with the sculpture by clicking it. By repeating this action, users can create as many associations as needed.
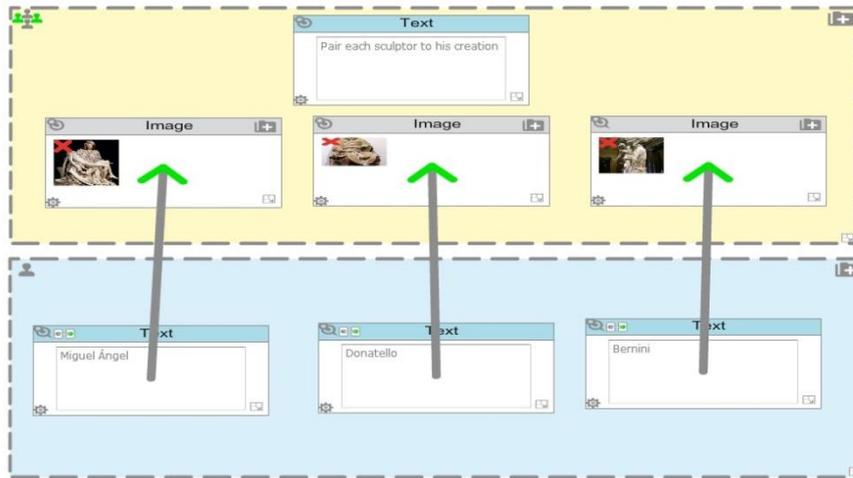
Figure 5. DEDOS-Editor, Pair-matching activity

3.4.3 Addition

Addition activities are similar to pair-matching activities. Students have to drag and drop cards with a numeric value onto another card, which will have the addition goal. When this goal is dropped onto a card, an icon is shown with a number that defines its value. The number can be changed by clicking the icon (see Figure 6).
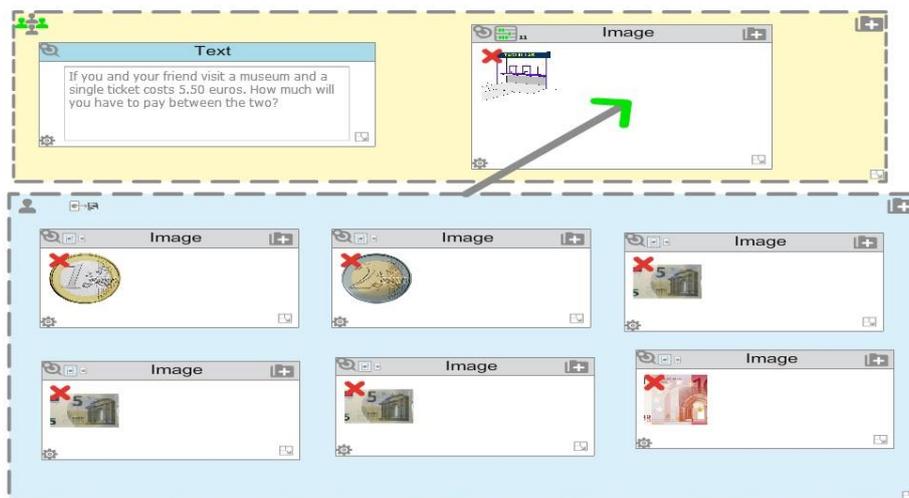
Figure 6. DEDOS-Editor, Addition activity

Then, the user must drop a pair-matching goal onto those cards which have to be dragged and dropped onto the card with the addition goal, establishing the association as explained in the previous section. By default, each card has a value of 1. This value can be changed by accessing the advanced options of the card and clicking the tab 'Maths', where the user will be able to add a new value or maintain the default one. Figure 6 shows an example of an addition activity related to money management.

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Since an addition activity can have a large number of cards and arrows derived from the pair-matching goals, the ease of use and visibility of the application could be affected. To solve this issue, DEDOS-Editor allows areas and cards to be paired. This means that the user can drag and drop a pair-matching goal into an area and associate it with a card; this means that all the cards in that area can be dragged and dropped onto the card indicated by the arrow, or that all the cards in one area can be paired with all the cards in another area. This functionality is available for this type of activity as well as for pair-matching activities. The example presented in Figure 6 shows a relationship between all the cards of a player area and another card, instead of creating six different and individual associations.

3.4.3 Connect the dots

In connect the dots activities, students must follow one or more sequences of points to form lines or shapes. To design this kind of activity, the user must add a player area to the editing area, then add an image to the background of this area by clicking the icon located at the top right corner of the area, as with image cards. Once the image has been added, the user can start designing the paths by dragging and dropping dot goals in the player area. The first goal establishes the first point on the path. Then, the user must repeat the process of adding goals until he/she completes the desired path. In the example shown in Figure 7, an incomplete image of a museum has been added to the player area, establishing a path that will complete the image when followed.

When goals are added, they will be added to the path that the user is creating at that moment, since each will attach to the last added point. To create new paths, the user must click the last goal to access to a menu where all the paths and points created are shown. Then, the user must drag and drop the last point to a new group (see Figure 8). When the user closes this menu, he/she will see that this point has been separated from the previous path. From here, the user must simply repeat the previous steps to continue designing new paths.
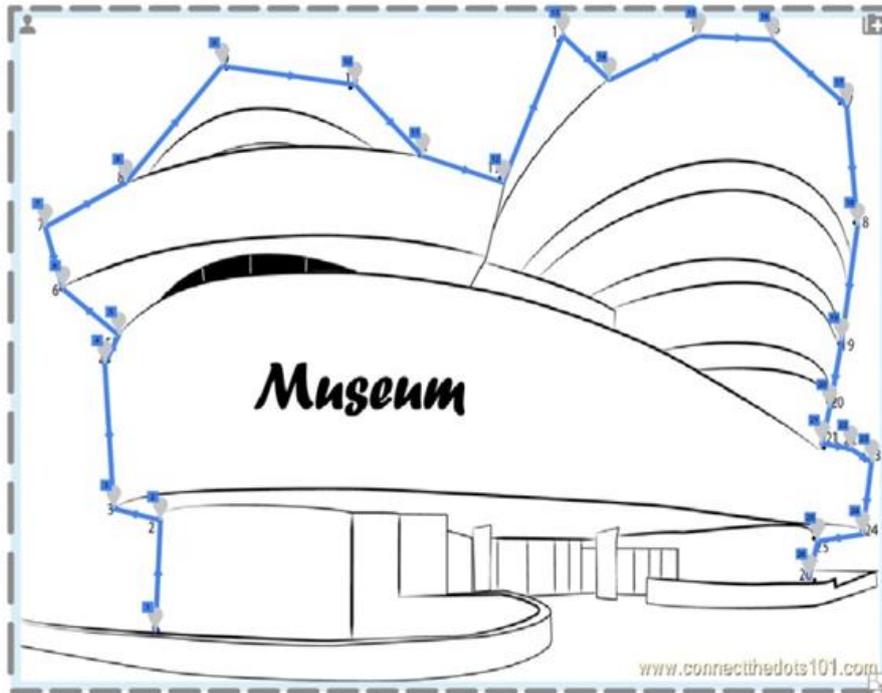
Figure 7. DEDOS-Editor, Connect the dots activity
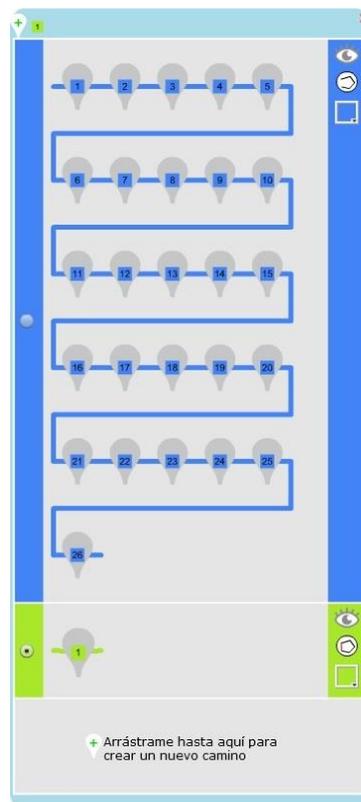
Figure 8. DEDOS-Editor, Connect the dots goal pop-up menu

3.5 D2XML

The next step was to model the features of the activities to create an XML which enables the exchange of data among applications. This model has been called D2XML. XML format has been used, since this is a data representation standard that can be read through any programming language. This will allow other developers to code their own players and easily use the information generated by DEDOS-Editor.

3.5.1 Project

The root element is called 'Project'. This root contains two main elements which store general data about the project and its activities. Firstly, the tag '<projectData>' includes the resolution used when designing the project '<resolution>', along with its width ('x') and height ('y'). The resolution is needed in order to scale the elements of the activities and adapt the content to the device where the activities will be performed. At execution time, DEDOS-Player and DEDOS-Web use this resolution and the device resolution to dynamically calculate the sizes and positions of the elements that appear in the activity. In addition, this section also stores the project language ('<language>') defined in the 'code' attribute (in the example presented in Figure 9, the language used is Spanish – 'es'). Storing the language will allow the application to localise menu labels and feedback messages used in both players. Secondly, the project stores the element '<activitiesList>' where the project activities are stored.

```
- <Project>
    - <projectData>
        <resolution y="893.3" x="1008"/>
        <language code="es"/>
    </projectData>
    - <activityList>
        + <Activity>
        + <Activity>
    </activityList>
</Project>
```

Figure 9. D2XML, Example of the general schema of a project

3.5.2 Activities

An educational project is composed of one or more activities. Each activity is stored in an '<Activity>' tag. An activity is always be made up of goals which are stored in the '<Objectives>' tag, a list of cards stored in a '<tokenList>' tag and a list of areas included in an '<areaList>' tag. Lastly, each activity stores the arrows that are created

when establishing pair-matching goals in the '<Arrows>' tag. Each of these elements is explained in the following sections.

3.5.3 Cards

Cards are the basic elements of an educational activity. Information about cards is stored in the '<Token>' element. The attributes of this element include its identifier, the type of card ('type'), which can be an image ('img') or text ('txt'), and its numeric value ('numValue'), which by default is '1'. Each card has its own configuration which is defined through the following properties.

- Position | '<pos>': This element details the spatial position of the card in the activity through its attributes 'x' and 'y'.

- Size | '<size>': This element details the size of the card through an attribute that contains its width ('width') and another attribute which contains its height ('height').

- Rotation | '<rotation>': Its 'value' attribute includes the card's rotation angle in degrees.

- Properties | '<clickable>', '<rotatable>', '<movable>', '<resizable>': These elements, whose 'value' attribute can be 'true' or 'false', determine whether the card can be clicked, rotated, moved or resized.

- Content | '<content'>: This element varies depending on the card type. If it is a text card, it will contain a '<text>' element that stores the text of the card. If it is an image card, '<content>' will include '<urlList>' element which will have the '<url>' where the images added to the card are stored. Lastly, the feedback ('<feedback>') of the card is stored in the <content>' element.

Figure 10 shows an example of a text card (left side) and an image card (right side) with all the elements and attributes detailed in this section. The '<Token>' tag can appear in a '<tokenList>' element within an activity, or in a '<tokenList>' element of an area, as explained in the next section.

Figure 10. D2XML, Example of a text card and an image card

3.5.4 Areas

Areas group the cards added into an activity (see Figure 11). Each area is stored in the '<Area>' element as part of an '<areaList>' element. Areas have similar attributes to cards: an identifier ('id') and the area type ('type'). The area type can either be 'game', which refers to an area which is common to all the players, or 'player', which refers to an individual workspace area for each player.

Figure 11. D2XML, Example of an area

The area is in a certain position that is defined through the '<pos>' element and its attributes 'x' and 'y'. Moreover, its size can be specified with the '<size>' element and its attributes 'height' and 'width'. Areas can be also presented with rotation through the '<rotation>' element and its attribute 'value'. Additionally, there is the possibility to add a background image to the area, which will be stored in the '<bg>' element along with its attribute 'url' containing the file name where the image is stored. Lastly, each area can have a card list ('<tokenList>') that stores all the cards ('<Token>') dropped into the area.

3.5.5 Goals

Activities have one or several goals which determine when the activity is complete. These goals can be found in the '<Objectives>' element of each activity, and the data about each goal is stored in the '<obj>' element. In our work, we have designed four types of goals: multiple-choice, pair-matching, addition and connect the dots. Each of these goals has its own attributes and elements which determine the condition the player must meet in order to end an activity; these are distinguished through the 'type' attribute.

- Multiple-choice: A multiple-choice goal is defined when 'type' has the value 'sel'. This type of goal also has an 'id' attribute to identify the card that will be clicked to complete it (see Figure 12).

```
<obj type="sel" id="instance2811"/>
```

Figure 12. D2XML, Multiple-choice goal

- Pair-matching: A pair-matching goal is defined when the 'type' attribute of the goal has the value 'pair'. This type of goal presents an 'origin' attribute which refers to the card that must be paired, and 'tokenMeter' values which can be 'true' or 'false'; this is used to determine whether the value of the 'origin' will be added to the value of the 'target' after pairing the cards (see addition activities). This goal has a list of targets that are stored in the '<targetList>' element, which contains the '<target>' element with an 'id' attribute that allows users to identify the card where the 'origin' card will be dropped. It is important to note that both the 'origin' and 'id' attributes could contain an area 'id', so it is possible to pair areas with cards, cards with areas, etc. Figure 13 shows an example of a pair-matching goal.

```
- <obj tokenMeter="false" origin="instance7103" type="pair">
    - <targetList>
        <target id="instance6154"/>
      </targetList>
  </obj>
```

Figure 13. D2XML, Pair-matching goal

- Addition: This goal is identified through the type 'tokenMeter', which is placed on the card with the identifier stated in the 'id' attribute (e.g. 'instance14541'). This will be the card onto which the player will have to drop the other cards until they add up to the requested value ('numValue'). In the example shown in Figure 14, this value is 11. Cards can be paired in the following two ways: through a list in the

'<originTokens>' element which contains all the single cards ('<token>') with their 'id' attributes, or through a list of areas '<originZones>' that contains areas ('<zone>') with their corresponding 'id' attributes ('instance14357'). When using an area as the origin of the association, the user determines that all the cards in this area can be dropped onto the card with the goal ('instance14541'). The pairing of the cards is performed as explained in the previous section.

```
- <objectives>
    - <obj numValue="11" id="instance14541" type="tokenMeter">
        <OriginTokens/>
      - <OriginZones>
            <zone id="instance14357"/>
        </OriginZones>
    </obj>
    - <obj type="pair" tokenMeter="true" origin="instance14357">
      - <targetList>
            <target id="instance14541"/>
        </targetList>
    </obj>
</objectives>
```

Figure 14. D2XML, Example of an addition goal

- Connect the dots: In this type of activity, it is possible to create several paths with different colours and identifiers. Each path is defined through a goal with the type 'path'. The attribute 'zone' stores the identifier of the area where the path has been created, the attribute 'id' stores the path identifier, and the 'pathColor' attribute saves the path colour. Paths are composed of several points that are stored through the '<checkpoint>' element, whose attributes include the point identifier ('id') and the position ('pos') the point occupies on the path. It is possible to create several paths in the same area. In this case, a new goal with the type 'path' and a different 'id' and 'pathColor' will appear in the '.xml' file, and this will be assigned to the same area ('zone') as the goal presented (see the example in Figure 15).

```
<obj pathColor="4359415" id="1" zone="instance10015" type="path">
    <checkpoint id="instance10069" pos="0"/>
    <checkpoint id="instance10134" pos="1"/>
    <checkpoint id="instance10174" pos="2"/>
    <checkpoint id="instance10210" pos="3"/>
    <checkpoint id="instance10301" pos="4"/>
    <checkpoint id="instance10320" pos="5"/>
    <checkpoint id="instance10386" pos="6"/>
    <checkpoint id="instance10480" pos="7"/>
</obj>
```

Figure 15. D2XML, Example of a connect the dots goal

In addition, in the area where the path or paths are added, a list of points represented in '<checkpointList>' will appear. In this list, the data related to each of the

points is stored ('<checkpoint>'). Each point has as attributes the 'id' (for instance, in Figure 16 one of the points has the 'id' 'instance10069', which corresponds to one of the points declared in the previous figures), its position ('x' and 'y'), its size ('width' and 'height') and whether it has an associated image ('image').

```
<Checkpointlist>
    <checkpoint image="null" height="23.75" width="15.35" y="153.45" x="62.35" id="instance10069"/>
    <checkpoint image="null" height="23.75" width="15.35" y="125.15" x="64.6" id="instance10134"/>
</Checkpointlist>
```

Figure 16. Example of points in an area

3.5.5 Pairing

Activities have a list where the arrows generated by a pair-matching goal are stored ('<Arrows>'). The data about each arrow is saved in the element ('<arrow>'), whose attributes contain the origin of the arrow ('origin') and its target ('dest'). In Figure 17, an example is shown in which three cards are paired with three other cards. Although the arrows could be drawn with the data from a pair-matching goal, the decision was made to separate these elements so that it would be possible to add new functionalities to the arrows such as colours, rotations or new arrowheads. This will not interfere with the pair-matching goal, since these are particular features of the arrow.

```
- <Arrows>
    <arrow dest="instance6154" origin="instance7103"/>
    <arrow dest="instance6458" origin="instance7674"/>
    <arrow dest="instance6756" origin="instance7969"/>
</Arrows>
```

Figure 17. D2XML, Arrows

CHAPTER 4: DEDOS-PLAYER

Once the educational project has been designed, students can solve those activities with DEDOS-Player or DEDOS-Web. These players dynamically adapt the content created for one player in DEDOS-Editor to the device where the activities will be performed. Moreover, they facilitate several options that can be chosen during execution time to transform a simple design into various learning scenarios. These features are especially important since during the design process teachers usually do not know, for instance, how many students will perform the activity at the same time and what device they will use.

4.1 Project configuration

Several parameters have been identified whose combination reshapes the way in which the activities can be solved. These parameters are configured once DEDOS-Player launches, allowing the behaviour of the application to be changed in order to create multiple learning experiences with just one project. Some of these options focus on changing certain behaviours depending on the project being solved individually or collaboratively. The parameters are the following:

- Number of players: Depending on the number of players that are interacting with the device, DEDOS-Player will adapt the game and the player areas, replicating the player areas as many times as necessary and placing the game area in the middle of the device. By default, there is one player solving the activities.

- Feedback: In order to give feedback on the players' actions through the cards they are interacting with, two options can be chosen: immediate or delayed. In the default option, immediate feedback, the player usually receives information about whether or not he/she has given a correct answer. Once an answer is given, the application will provide the corresponding feedback. If all the goals are completed, the activity will end automatically. On the other hand, if delayed feedback is chosen, the player could perform as many actions as desired before confirming the given answers. In this scenario, DEDOS-Player will include a confirmation button that the user must click so that DEDOS-Player can check the given answers. In that moment, the application will show the corresponding feedback.

- Answering structure: The teacher can choose whether the students will interact simultaneously or sequentially. In the first mode, students interact at the same time

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(default option), while in the second mode only one user will have control at any given time. In addition, the last mode could be configured 'by turns', in which the turn goes to the next player once the student has solved the activity. Another option is 'by interaction', in which the turn goes to the next player after the student performs an action (clicking a card, pairing two cards, etc.).

- Number of required answers: Through this option the teacher can determine whether all users have to answer the activity in order to move to the next one. By default, only one answer from one user is needed to go to the next activity.

- Right answer required: With this option the teacher can force the students to solve the activity correctly in order to advance to the next one. If the students provide an incorrect answer, they will have to restart the activity. By default, this option is not activated.

- Score mode: The result of an activity in DEDOS-Player is measured through a points system, adding one point for each right answer and subtracting one point for each wrong answer (the score never goes below 0). This mode allows teachers to determine the way in which the points will be assigned. In the collaborative mode, the points that each player earns are added to a common counter, while in competitive mode each player has his/her own counter. By default, this option is set to collaborative.

- Answer consensus: With this option the teacher can configure whether consensus in the answer is needed in order to advance to the next activity. If activated, this option aims to have students discuss the answers so that they enhance their social and communication skills.

All these options are available before starting the educational project. The following basic options are shown after loading the project: number of players, feedback, and answer dynamics (see default basic options in Figure 18). If the teacher wants to set the advanced options, he/she must click the button 'Advanced'. Once the project has been configured, students can start the activities by clicking the button 'Start'.
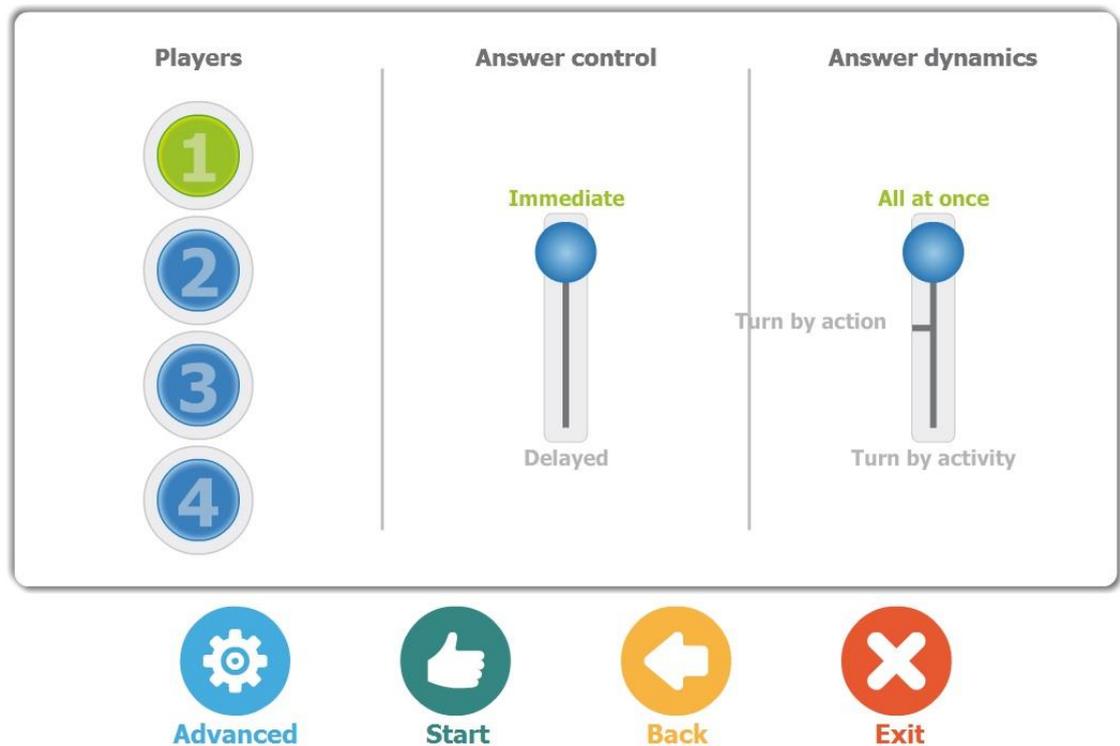
Figure 18. DEDOS-Player, Basic options

4.2 Technology

To design DEDOS-Player, ActionScript was used, which is usually combined with Adobe Flash. An object-oriented programming approach was used to design an application in which each element controls its own behaviour and does not depend on other elements to accomplish its function. The designed classes are integrated with the elements of the graphical user interface, which helped to design a simple but functional interface. More details about the implementation are shown in Roldán-Álvarez, et al. (2011).

Since the interaction with the application is based mainly on clicks and drag and drop actions, DEDOS-Player needed a library which supports these types of events, both when executed with a mouse and when performed through gestures on touch devices. To do so, Fling was used (Llinás et al., 2011), a library which allows multi-touch applications to be developed using Adobe Flash, Adobe Air and Adobe Flex. Its modular structure is focused on the inclusion of multiple interaction methods so that the applications can be used on any device.

4.3 Graphical user interface

Depending on the options chosen before starting the educational project, DEDOS-Player will show slight differences in its interface and behaviour. Figure 19 shows the multiple-choice activity designed in Figure 4. In this example, the teacher has decided that two students will perform the activities and will solve them by turns, maintaining the default values in the remaining options. If the student answers incorrectly, the chosen card will be highlighted in red, showing the feedback the teacher included on that card at the same time. If there is no feedback on the card, the student will only see the red frame and a text saying that he/she has chosen a wrong answer. The right answers are highlighted in green, with a symbol for correct over the card. In the example on Figure 19, it is the turn of player number one. Player number two has answered, choosing one right answer and one wrong answer.
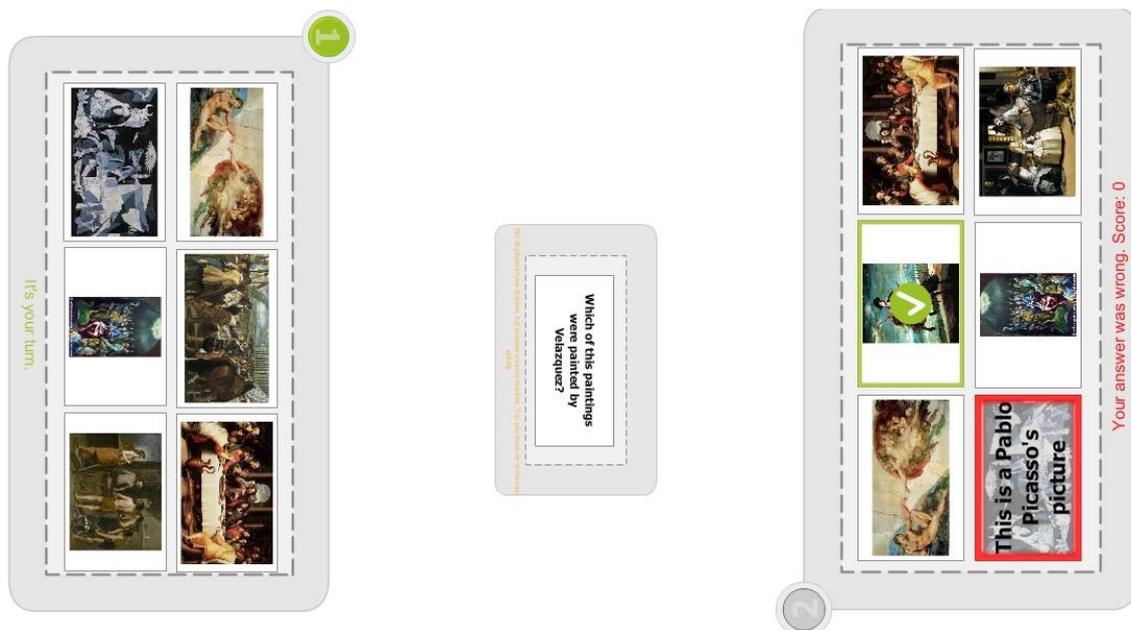
Figure 19. DEDOS-Player, Multiple-choice activity, Feedback example

In order to show pair-matching and addition activities, we will focus on the latter since they are closely related. In pair-matching activities, students have to drag and drop cards onto the corresponding cards, while in addition activities, students have to drag and drop cards until the added value of those cards is the same as the value defined in the addition goal when designing the activity. Figure 20 shows how three students view the activity defined in Figure 7. Each student has to drag cards from his/her player area until the total value of the dropped cards is 11. In this example, each time a student drags and drops a card with a bill or a coin onto the card which represents the ticket office, the

numeric value associated with that card appears and is counted in order to complete the addition goal. Because of the design of this activity, students can solve it in different ways, provided that the total result of the added cards is indicated by the activity creator.
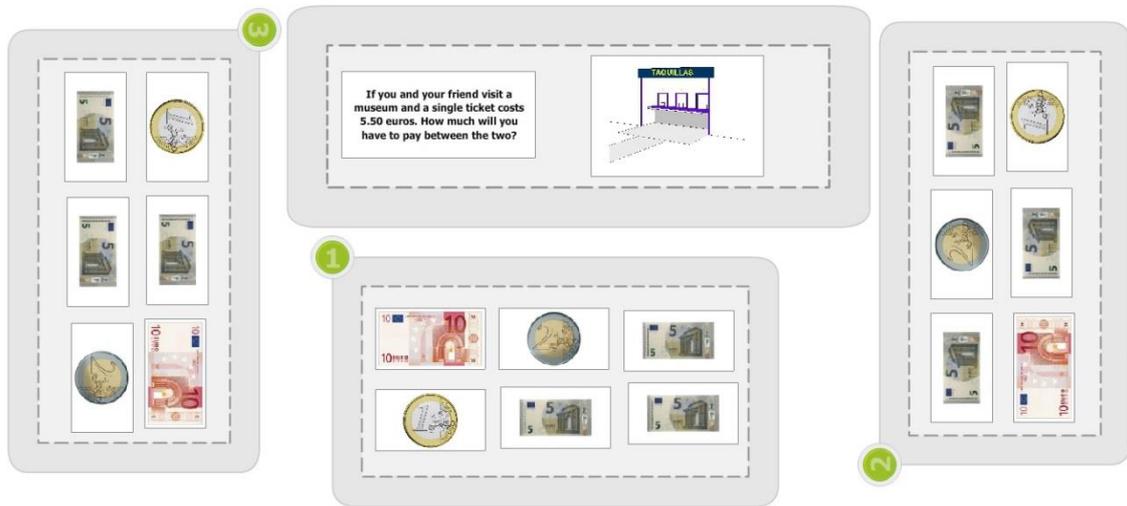
Figure 20. DEDOS-Player, Addition activity with three players

Lastly, Figure 21 represents the students' view of a connect the dots activity. In this example, the activity designed in Figure 15 is shown. In this kind of activity, the student will see several points that he/she must follow with his/her finger, if using a touch surface, or with the mouse if using another device. While the user follows the path, a line is drawn that can be one of three colours: black, if the user is following the path correctly; orange, if the user is diverging from the path; or red, if the user is too far away from the path. The activity will end once the user follows all the points on all the paths in his/her player area.
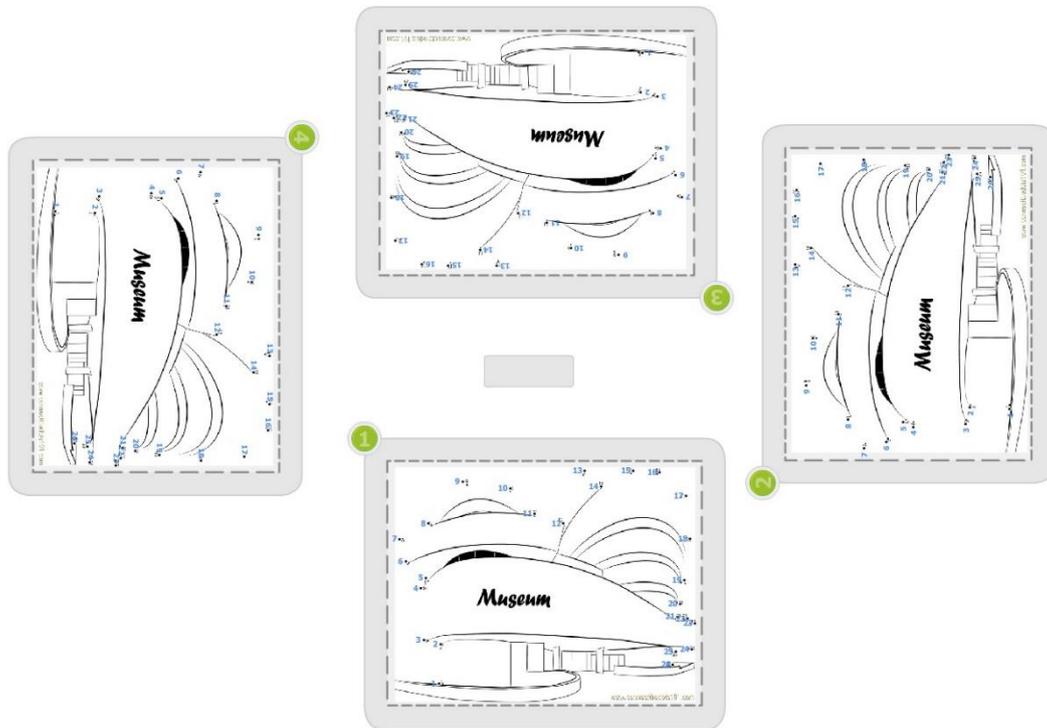
Figure 21. DEDOS-Player, Connect the dots activity

4.4 Stored data

Fleck et al.'s (2009) study shows the importance of analysing students' actions to understand their strategies depending on the device they are using, and especially when they interact at the same time on a multi-touch tabletop. Martínez-Maldonado et al. (2013) proposed a set of recommendations to build systems which capture students' actions and general information about their interaction automatically. With this data, applications can provide support in the form of visualisations, participatory indicators and adapted actions, while teachers can analyse students' performance, adapt their own projects and detect common issues among the students.

```
<configuration>
    <numPlayers>3</numPlayers>
    <delayedFeedback>true</delayedFeedback>
    <answerDynamic>Simultaneous</answerDynamic>
    <requiredAnswers>All</requiredAnswers>
    <success>false</success>
    <scoreMode>Collaborative</scoreMode>
    <consensus>false</consensus>
</configuration>
```

Figure 22. DEDOS-Player. Project configuration

In DEDOS-Player, a log system stores the project configuration chosen by the teacher and the different events that happen in the application (see Figure 22). Currently,

there are four types of events (interaction, feedback, score and next/back). These are detailed below:

- Interaction: This represents an interaction that a user has had with a card. This event can be a click or a pair movement (see Figure 23). In addition, apart from the data associated with the interaction (such as the card and event), a timestamp, the player identifier and the activity identifier are also stored.

```
<Event type="Interaction">
    <date>2015-10-10 20:21:33</date>
    <player>1</player>
    <activity>1</activity>
    <card>instance1825</card>
    <event>Click</event>
    <Message/>
</Event>
```

Figure 23. DEDOS-Player, Interaction log

- Feedback: This represents the answer given by the application in response to a user's interaction with a card (see Figure 24). For instance, if the user clicks a card in a multiple-choice activity, this will generate a log to indicate whether or not this card is part of the correct answer of the activity. If it is a pair-matching activity, this log will contain the two paired cards and indicate whether the association was correct.

```
<Event type="Feedback">
    <date>2015-10-10 20:21:33</date>
    <player>1</player>
    <activity>0</activity>
    <Message>Player 1 has selected the card
            instance1825 and it was a correct answer
    </Message>
</Event>
```

Figure 24. DEDOS-Player, Feedback log

- Score: This stores the score of a player in an activity (see Figure 25). When all of the activities are finished, a log will be generated to show the overall score of a project. It should be taken into account that scoring method depends on the option chosen when starting DEDOS-Player, as mentioned in Section 4.1 Project configuration.

```
<Event type="Score">
    <date>2015-10-10 20:21:45</date>
    <player>1</player>
    <activity>1</activity>
    <score>1</score>
</Event>
```

Figure 25. DEDOS-Player, Score log

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- Next/back: This registers whether the users have advanced to the next activity or gone back to the previous one, showing the activities the students were working on and the timestamp for when this event happened (see Figure 26).

```
<Event type="Next">
    <date>2015-10-10 20:21:45</date>
    <activity>1</activity>
    <Message>The users have advanced to the next activity</Message>
</Event>
```

Figure 26. DEDOS-Player, Next/back log

CHAPTER 5: DEDOS-WEB

The constant growth of connectivity in schools, combined with the wide range of available devices and the limitations of DEDOS-Player, led to the development of DEDOS-Web. Moreover, more functionalities were added that allow all the projects to be stored in the same workspace and work groups to be created. The following sections describe the motivation and the technology used. In addition, the graphical user interface, data storage and learning analytics service are explained.

5.1 Motivation

Including applications to support education that do not require installation on a computer offers a broad range of possibilities to offer new activities and interaction models to students. In addition, the potential of mobile technologies has opened a new path in research about the use of technology in education. In particular, designing applications for these new devices raises new design challenges not only associated with the physical space and functionality limitations of this technology, but also related to implementing new design paradigms: collaborative, customisable and contextual learning.

After using DEDOS-Player in different learning experiments, new needs arose that motivated the development of DEDOS-Web. Firstly, using DEDOS-Player requires its installation on all of the devices where the teacher wants to run this tool. When students are using mobile devices such as tablets in the classroom, this task can be tedious with regard to the time required. Second, and related to the previous situation, we find that most schools have an ICT coordinator, and for some this service is outsourced. Occasionally, this coordinator or service does not know teachers' motivation when installing a new tool on their computers, which leads to its uninstallation without previous warning. Web technology has been used to solve the problems derived from having to install DEDOS-Player, while maintaining tactile interaction when it is executed on tablet computers and multi-touch tabletops. In this way, the application can be accessed from any device with an Internet connection, which eliminates the need to install the application on all the devices where it will be used. Moreover, it will not be necessary to reinstall the application each time there is an update; this helps to solve bugs in a way that is transparent to the user, and allows the platform to continue to evolve.

In addition, through DEDOS-Web it is possible to implement learning analytics in a more precise way. Previously, the teacher had to analyse the logs generated by DEDOS-Editor since there was no tool that showed these analytics in a simple way; this task was too complex for many teachers. With this development, the aim is to enhance the way in which students' information is stored, as well as the way this information is presented to teachers. The implementation of a learning analytics service will add new value to the functionality offered by DEDOS-Player.

From the students' point of view, when they performed activities on tablet computers, they did so in an individual way. DEDOS-Web allows various students to solve the same project from different places in a collaborative way, even without being physically in the same place. With DEDOS-Player, teachers had to add the file with the project on all the devices, which requires a great effort. Additionally, since the students were not connected, they were not aware of their peers' actions. Through DEDOS-Web, teachers only have to upload the educational project once so that all the students can access it through a web browser, thus reducing teachers' workload. In addition, all the students solve the same project, so it is possible to design a collaborative environment in which everyone solves the same activity.

Lastly, it is worth mentioning that connect the dots activities have been excluded from this development. This activity was designed exclusively to train motor skills through interactions with multi-touch tabletops. Although DEDOS-Web can also run on these surfaces, the experiments conducted indicate that teachers who used DEDOS-Editor did not usually design this type of activity. This is why in this first version of DEDOS-Web, efforts have been focused on the implementation of multiple-choice, pair-matching and addition activities.

5.2 Technology

To design DEDOS-Web, several technologies were used in order to implement the server-side, the client-side and the API through which the user can consult the learning analytics service. The learning analytics service was separated from the main development in order to avoid overloading the main service, although both will be in constant communication. The main service will constantly send data to the learning analytics service, which will then process this data. Once requested, the learning analytics service will send the processed data back to the main service.

DEDOS-Web is composed of a server-side developed with Node.js and a client-side developed in JavaScript. MongoDB was used to implement a database which allows the necessary data to be stored both for the main service and the learning analytics service.

Both server-side and client-side technologies use the same programming language. Node.js is prominently used when developing real-time web applications. After 20 years of using the request-response paradigm, several technologies have been developed in order to provide bidirectional connections where both the client and the server can start the communication, allowing free data exchange. Node.js facilitates a simpler way of building scalable applications. In our case, we wanted to develop an application with the possibility for many users to access it at the same time, so scalability was a factor to take into account. With current technology, for instance PHP, each new connection creates a new thread that consumes around 2MB of memory. If there is a server with 8GB of RAM, only around 4,000 users can connect, which will force the developer to use more servers if the number of users surpasses that quantity. Node.js overcomes that problem, since every time a user connects, the connection launches a new event within the process of its engine.

On the other hand, MongoDB is being used as a database for these services since it is a technology that facilitates building applications quickly, managing a wide range of data, and managing the scalability of applications in an efficient way. In MongoDB, data is mapped in a natural way for object-oriented programming languages. Using MongoDB eliminates the complex layer that translates objects in the code to tables in databases. The flexibility of this model allows the database schema to be updated as new requirements arise.

Figure 27 shows the architecture of DEDOS-Web and depicts how the user connects to the client-side, both as teachers to create classrooms and upload projects, or as students to solve activities. This access can take place through any device with an Internet connection, and the application will adapt the interface depending on the device used. However, users cannot directly access the database. The server-side of DEDOS-Web will act as an intermediary to store information and to send it when requested. On the other hand, the learning analytics service is independent of DEDOS-Web. This service will obtain data from DEDOS-Web continuously, and this data will be processed and stored in the database (right answers, times, clicks, number of tries, etc.). When the teacher wants to check information regarding the activities performed by a student in a

certain project, DEDOS-Web will access and display this processed data without the need for any further processing, thus speeding up DEDOS-Web.
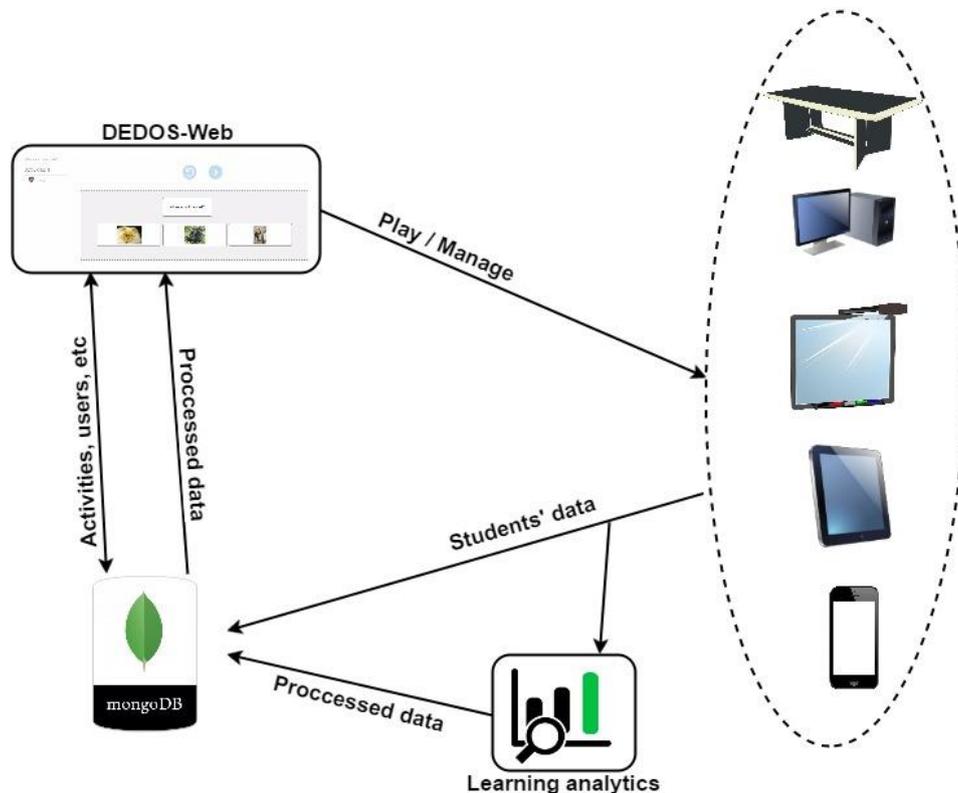
Figure 27. DEDOS-Web architecture

The technology detailed in this section allows us the possibility to integrate new languages in a simple and easy way. Currently, DEDOS-Web supports two languages (Spanish and English), but by adding a file with the translation of the elements of the user interface on the server, more languages could be added.

5.3 Graphical user interface

This section presents the interface for both teachers and students. The teacher's dashboard will be used to upload projects, add classrooms and students, and view the results of the students once they start solving activities. On the other hand, the student's view allows them to access the educational project assigned by the teacher, choose their user name and solve the proposed activities.

5.3.1 Teacher's dashboard

In order to access the teacher's dashboard, the teacher first has to sign up as a user on the platform. To facilitate this step, several login methods have been implemented: login with a user name and password, or login through a Twitter or a Facebook account.

Once the teacher logs in, he/she will go directly to the teacher's dashboard. The main window of this dashboard allows the user to upload a new project and assign the students that will perform it. On the left, there is a menu containing three groups: i) start, which currently shows a form to upload a project; ii) classrooms; and iii) projects. This left menu appears in every section of the teacher's dashboard, but with the goal of enhancing the screenshot view, it is omitted in the following figures. In the top right corner of the panel there is an icon that, when clicked, will allow the teacher to change his/her configuration (password and personal data, among others), along with an option to disconnect from the platform.

The 'Classroom' option on the menu is divided into two subgroups: 'my classrooms' and 'add classroom'. The first time the teacher connects to the platform, there will not be any classrooms and thus the option 'my classrooms' will be empty. To add a new classroom, the teacher must click the button 'add classroom' so that the platform shows the form presented in Figure 28. This form requires basic data such as the name of the classroom and the educational level. Moreover, the teacher can add the students who are a part of that classroom. These students can be added by: importing them from other created classrooms; adding their name, surname and an image; or importing them through an Excel file that the teacher has previously created by following the format provided with the platform. The Excel file will reduce the time required for teachers to add students, as they will only need to add new class members manually. The teacher can add a classroom without students if desired, and there is no maximum number of students that can be added into a classroom. If the teacher does not add an image for a student, DEDOS-Web will generate a default one that consists of an icon with the student's first two initials.

To show how the platform works, we will imagine that we have created two classrooms: 1A for childhood education and 2A for primary education, with six students each. Once created, teachers can see these in the section 'my classrooms' (see Figure 29). Furthermore, teachers can add a new classroom and edit or delete an existing one. When editing a classroom, the teacher can change its name and educational level, and add or delete students. The teacher can also invite other registered users in the platform to be administrators for a created classroom. The invited user will not be allowed to delete this classroom, but he/she can disconnect from it. This way, teachers who lecture in the same course can have the same students in the platform without any additional effort, since they will only have to add the students once.
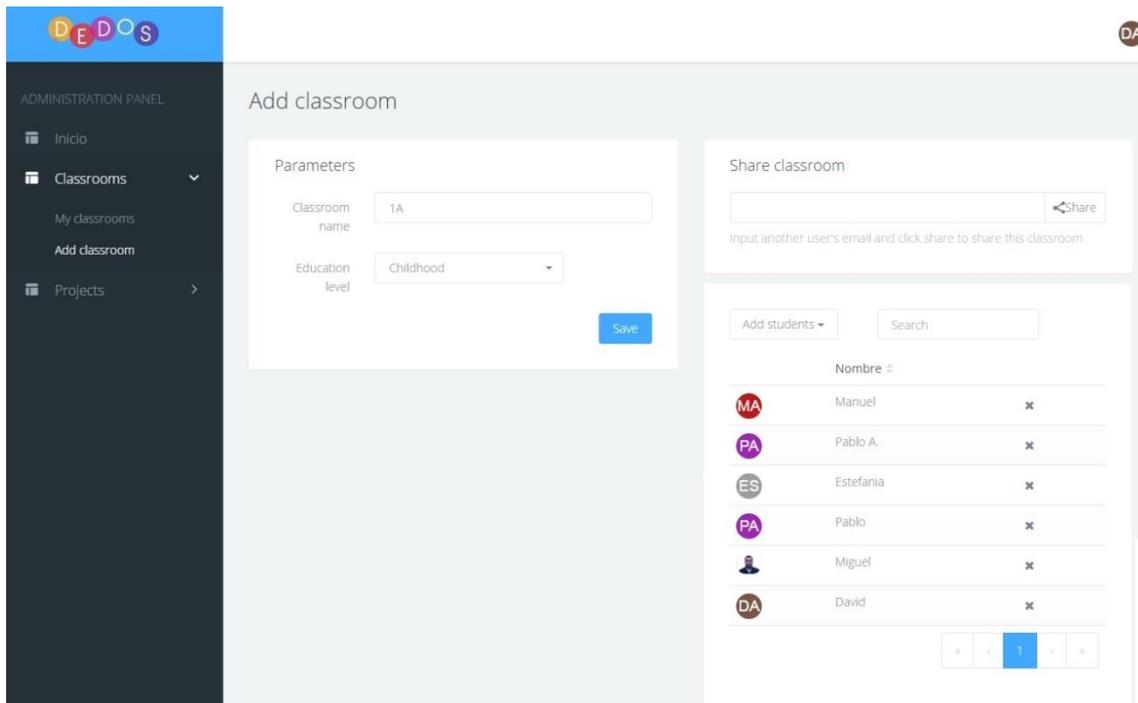
Figure 28. DEDOS-Web, Teacher's dashboard, Add classroom
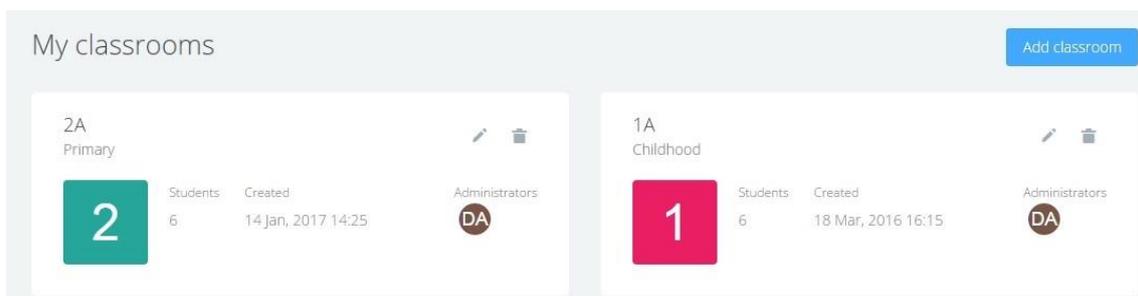
Figure 29. DEDOS-Web, Teacher's dashboard, My classrooms

Once the classrooms have been added, teachers may add a new project. To do this, the teacher must access 'add project' within the menu 'projects'. Figure 30 shows the form were the teacher can choose a name for the project and the .zip file which contains the project created with DEDOS-Editor. In addition, the teacher can choose an educational level, a subject or area of knowledge according to the project, and a description which will help to identify the project. Next to the form, the teacher can add the students he/she will assign this project to. The teacher can add these students either by importing them from the classrooms he/she has created, entering them manually student by student, or importing them through an Excel file.
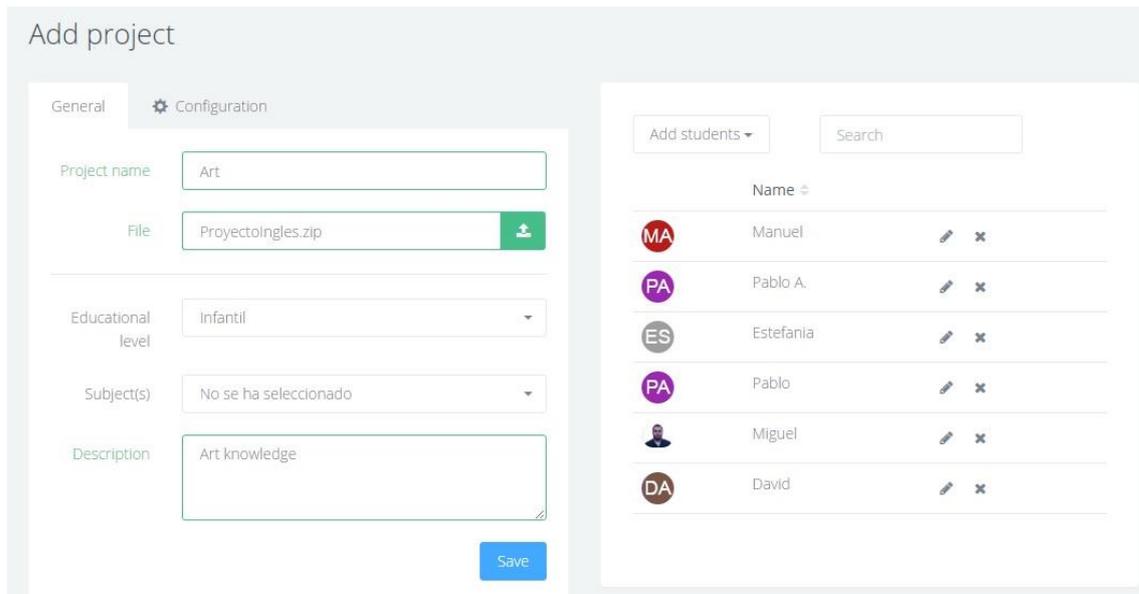
Figure 30. DEDOS-Web, Teacher's dashboard, Add project

Through the configuration tab, the teacher can define several parameters as can be done with DEDOS-Player. The main difference is that through DEDOS-Web teachers can change the configuration while the students are doing the activities, instead of having to reload the project and make the students start again from scratch.

Figure 31 shows the options available to configure a project. We have removed some of the options which appear in DEDOS-Player, since these were not useful for a web platform. DEDOS-Web does not include options such as: i) number of players, which has been removed since DEDOS-Player is meant to be used by individual users on individual devices such as personal computers, tablets and smartphones; ii) number of players who answer, removed since DEDOS-Player is an individual application which always requires one player to answer; iii) score, removed since it was not used in DEDOS-Player; and iv) consensus, removed since it would imply that several students are doing the project at the same time and communicating amongst themselves through means outside of DEDOS-Web. On the other hand, DEDOS-Web includes new options that are detailed in the following paragraphs: i) teachers can decide if they want the students to solve the activities in groups, and can determine the maximum time they have to wait in order to proceed with the activity; ii) go forward automatically, which prevents students from restarting an activity or going on to the next one, which can be done automatically; iii) fail not allowed; and iv) navigation. In summary, the options available in DEDOS-

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Web are as follows: turns, go forward automatically, right answer required, fail not allowed, delayed feedback and navigation:

Figure 31. DEDOS-Web, Teacher's dashboard, Project configuration

- *Turns*: This option determines whether the students can solve the activity at the same time. If not, the application establishes a turns system in which the students have to answer one by one and cannot interact with the application until it is their turn. Within this option, the teacher can define workgroups and choose how many students will be in each one. Currently, groups can only be formed if this option is activated. These groups will be dynamic, which means that they are generated by DEDOS-Web. These

groups are created according the entry order of each activity, which means that if four different students from four different groups end the same activity at the same time and go forward, DEDOS-Web will join them into the same group. Lastly, the teacher can define a maximum wait time. Ideally, if the teacher defines groups of four people to solve a project at home, they will connect to DEDOS-Web at the same time. However, if any member of the group does not connect and the rest finish the activity, they cannot advance to the next one and will be stuck. To avoid this scenario, if the users connect solve the activity and one or more members of the group are not connected, the maximum wait time option allows them to go to the next activity once this time concludes.

- *Go forward automatically*: This option allows teachers to define whether or not those actions which are not related to the activity itself will be done automatically by DEDOS-Web. For instance, users can automatically advance to the next activity when they have finished the current one without having to click the corresponding buttons. If this option is activated, the teacher will have to define the time that needs to pass until this action occurs.

- *Right answer required*: This option, which is also present in DEDOS-Player, establishes whether it is necessary to solve an activity correctly in order to go to the next activity.

- *Fail not allowed*: Through this option the teacher can configure whether, in the case that the student chooses a wrong answer, the activity will end and fail automatically. This option is closely related to the previous one. For instance, if we require the student to solve the activity correctly, but specify that he cannot fail an answer, then in the moment he fails one of the answers the activity will end. However, since it is compulsory to solve the activity correctly, the student will have to restart it. This restart action will be performed automatically if the option 'go forward automatically' is activated.

- *Delayed feedback*: As in DEDOS-Player, with this option the teacher can determine whether the feedback will be provided immediately or delayed. If this option is not activated, each time the student chooses or pairs a card, the application will offer feedback about this interaction. To the contrary, with delayed feedback the student will be able to interact with the activity and click, unselect and pair the cards as many

times as he/she wishes. Then, once the student is satisfied with the answers given, he/she will have to click the check button, which will check the activity.

- *Navigation*: The teacher can configure if the activities will have to be completed sequentially, or if the student can navigate through the activities and resolve them in the order he/she considers appropriate.

Once the teacher has added his/her project(s), he/she can view the project list in the section '*my projects*' within the menu '*projects*' on the left side (see Figure 32). Through this section the teacher can add more projects, delete existing ones, duplicate them or access the project management panel by clicking on the thumbnail that represents its first activity.
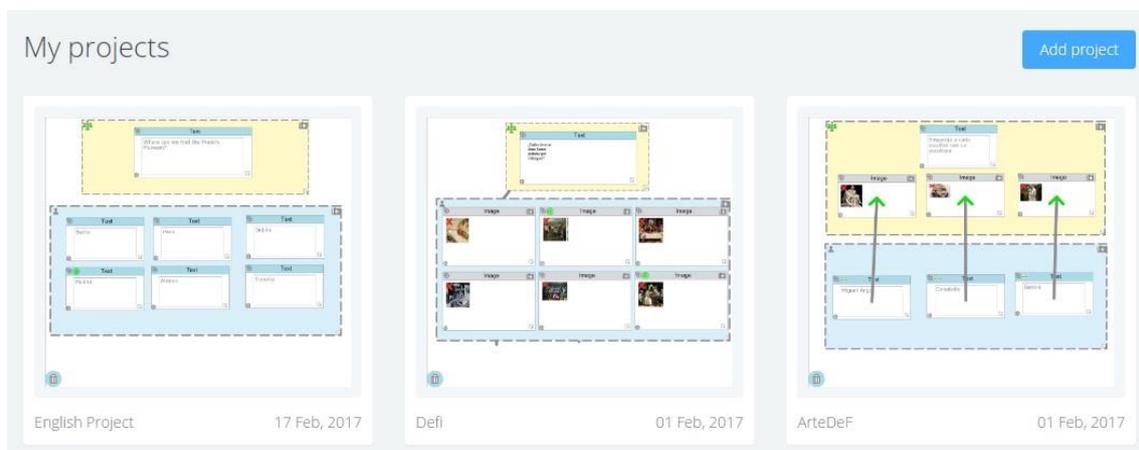
Figure 32. DEDOS-Web, Teacher's dashboard, My projects

If the teacher clicks on the thumbnail which represents the project, the management panel of the project will open as shown in Figure 33. Firstly, there is a menu to navigate to the configuration panel where the teacher can add more students, change the project's configuration or go back to the main management section. Moreover, this panel shows the project code, which the students can access through the link that appears in the section '*how to play?*'.

The teacher also has access to a section where he/she can see the students assigned to the project. The icon that represents this allows the teacher to observe if the students are connected (green circle) or not connected (grey circle) at that moment. This section also shows the progress of the student through a circular diagram which will be filled as the student completes activities, and a status which will indicate the current activity the student has to solve.

In addition, there is a section where the teacher can visualise the activities. Next to each activity thumbnail is an indication of whether or not the students have completed the activity correctly. Moreover, teachers can download an Excel file which contains information about each student and activity. The second tab in the file shows all of the answers that each student has given, indicating whether the answer is part of the solution or not. This way, teachers can download the students' results in a known and changeable format, which will allow them to make their own annotations in that document and process the presented data.
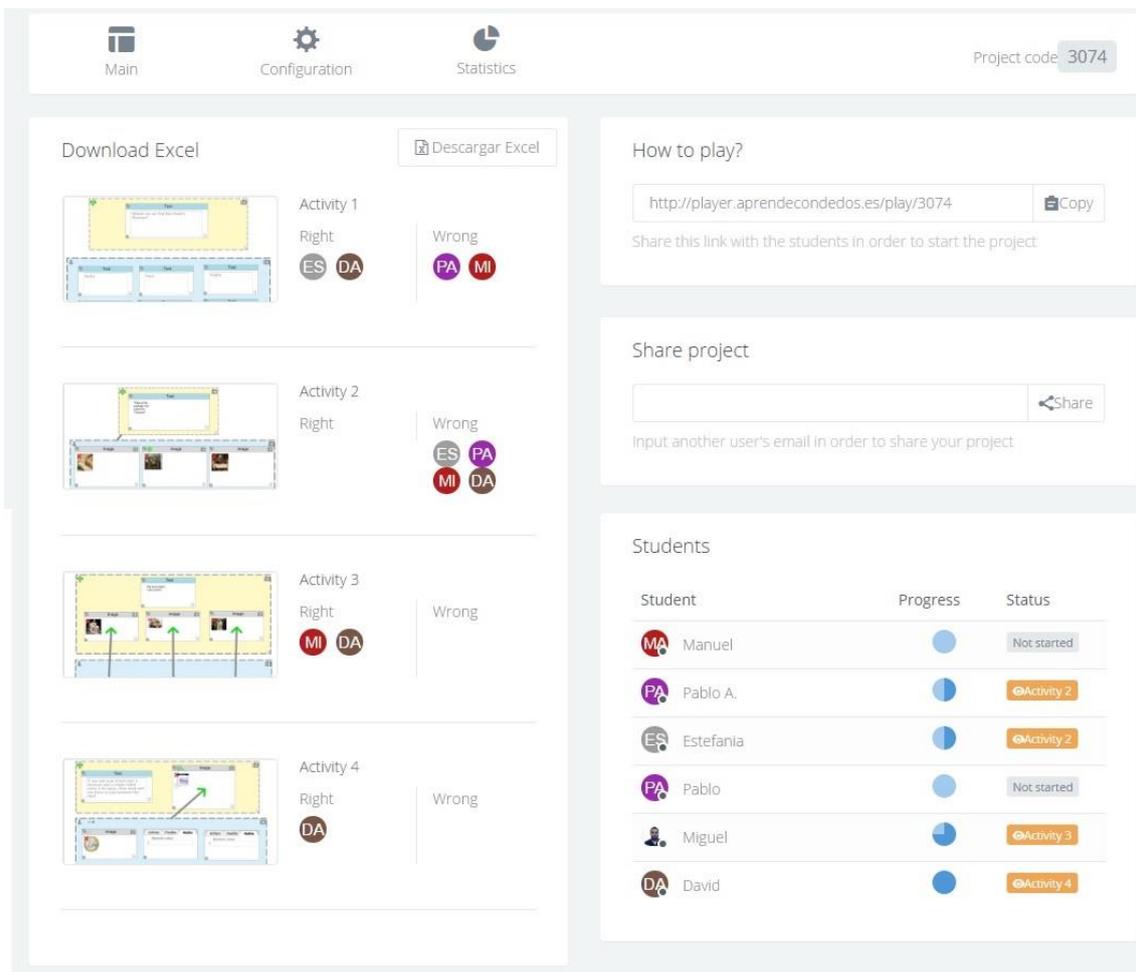
Figure 33. DEDOS-Web, Teacher's dashboard, Project management panel.

Lastly, it can be observed that through the upper menu it is possible to access a statistics section. This provides the teacher with access to the information gathered from the learning analytics service. Currently, this section has three graphs in which the results of the students' interactions with the project are summarised (see Figure 34).

The first graphs show the general progress of the project, where the teacher can see a pie chart which represents the percentages of the following: number of activities

solved correctly, number of activities solved incorrectly, and number of activities that have not yet been solved. When the teachers move the mouse over each sector, it will show the exact number of corresponding activities.
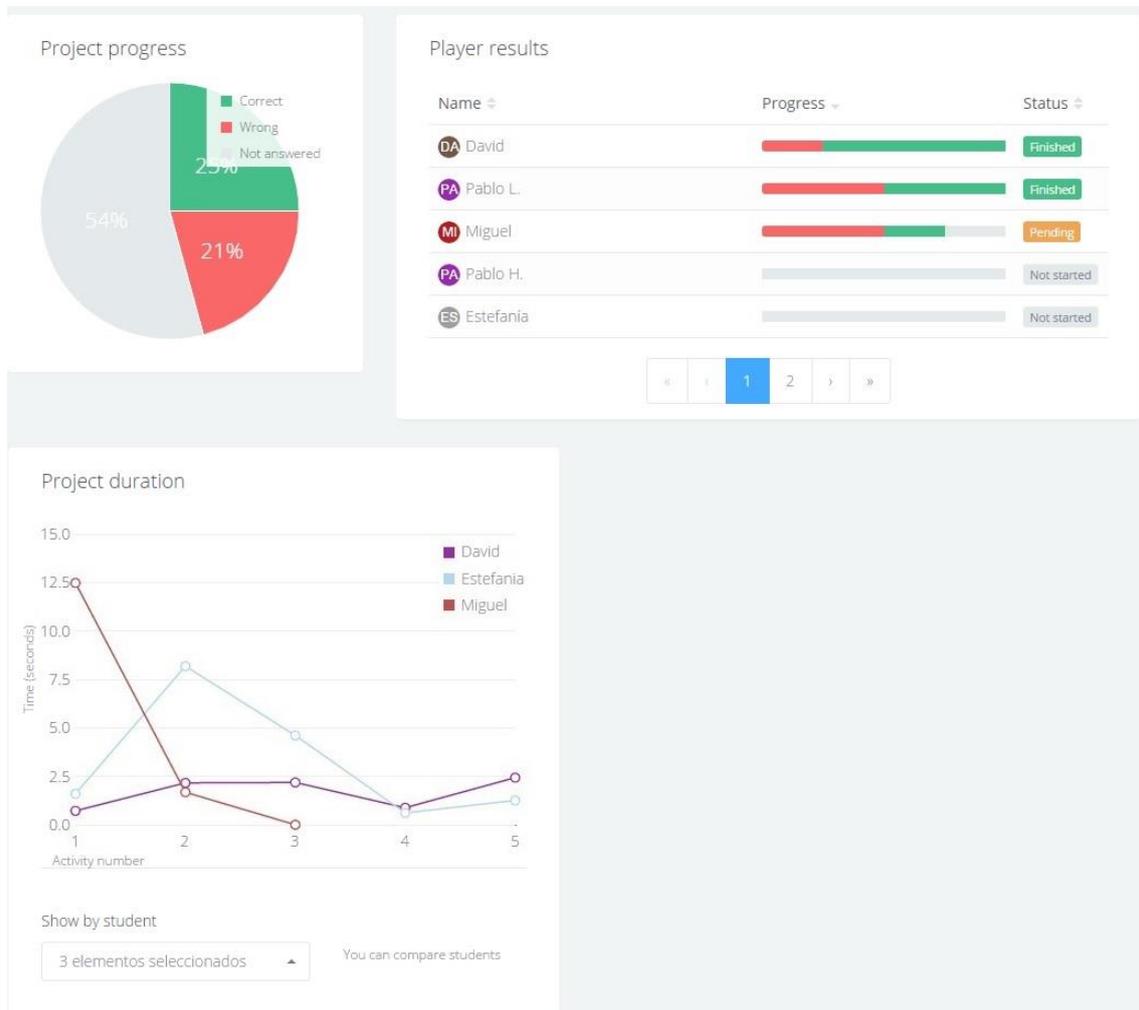
Figure 34. DEDOS-Web, Teachers' dashboard, Learning analytics

Next to the previous graph, teachers can review the activities that each of the students have solved correctly or incorrectly. Moreover, to the right of this graph is an identifier which allows the teacher to see which students have finished the project, which are still doing it and which have not yet started. As in the previous graph, when the teacher moves the mouse over the bars, he/she will see the exact number of activities which have been solved correctly and incorrectly.

Finally, at the bottom there is a graph which shows the amount of time spent by each student to solve each of the activities. It is important to highlight that teachers can simultaneously show the data of as many students as he/she desires by using the dropdown menu below the graph. This will allow teachers to compare times across all

students, detect if one activity was more difficult than the others, and determine whether a student had problems with a specific activity.

5.3.2 Student's view

This section describes the graphical user interface for the students, and how they can interact with it. In the following paragraphs, the project configuration is adjusted in order to observe the ways in which these changes affect both what the student sees and the how the application behaves as the student answers.

The first step is that the student gains access to the project created by the teacher. To do this, the teacher should provide the link to the students; this link is found in the section 'how to play?' shown in Figure 33. In addition, students can start the project by navigating to the link http://player.aprendecondedos.es/play and then entering the project code. Once a student accesses the project, he/she will choose from the list of students the teacher has assigned this project to (see Figure 35). This way, DEDOS-Web will store information about the student's interaction, answers given, tries per activity, etc.

Figure 35. DEDOS-Web, Student's view

Then, the first activity of the project will load. In this example, the first activity will be performed with the default configuration explained in Figure 31. The student's view is divided into two main areas: the right side contains information about the project name, the activity that the student is doing at that moment and the students who are connected simultaneously; in the middle of the screen, there is an area where the elements

of the activity itself will appear with buttons that will allow the student to go to the next activity, go back to the previous activity or restart the current activity.

If the student selects a wrong answer and the option '*fail not allowed*' is not activated, the student will be able to keep answering until selecting the right answer for the activity. Figure 36 represents the status of the application once the student has chosen a wrong answer ('Berlin') and then the right answer ('Madrid'). The activity is finished, albeit incorrectly since the student has given an incorrect answer. Since in this example the option '*right answer required*' is activated, the student must solve the activity correctly. He/she can then advance to the next activity by clicking the right arrow, since the option '*go forward automatically*' is not activated.
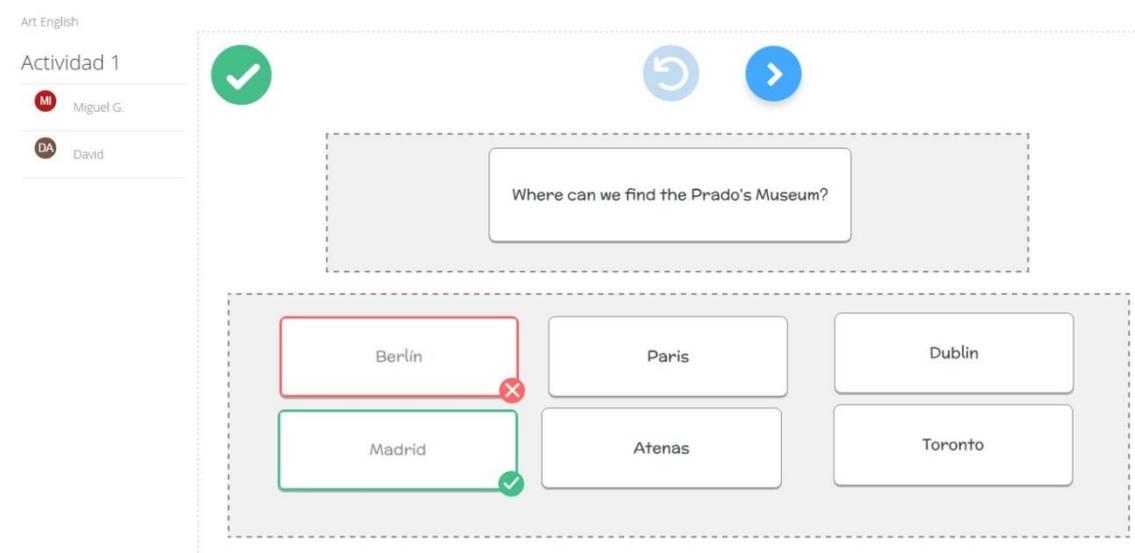
Figure 36. DEDOS-Web, Student's view, Multiple-choice

If the teacher activates the option '*go forward automatically*', DEDOS-Web will show a message in the top right corner where the student will be informed that the application will go to the next activity in the stipulated time. Activating this option does not prevent the user from advancing to the next activity by clicking the corresponding button.

The next activity is the multiple-choice activity designed in Figure 4. If the teacher decides to activate the 'delayed' feedback option, the student will be able to select and unselect cards until he/she wants to validate his/her answer. Then, the student will have to click the check button that will appear in the bottom left corner of the screen so that DEDOS-Web will evaluate the answers. Figure 37 shows this activity once it has been solved correctly.
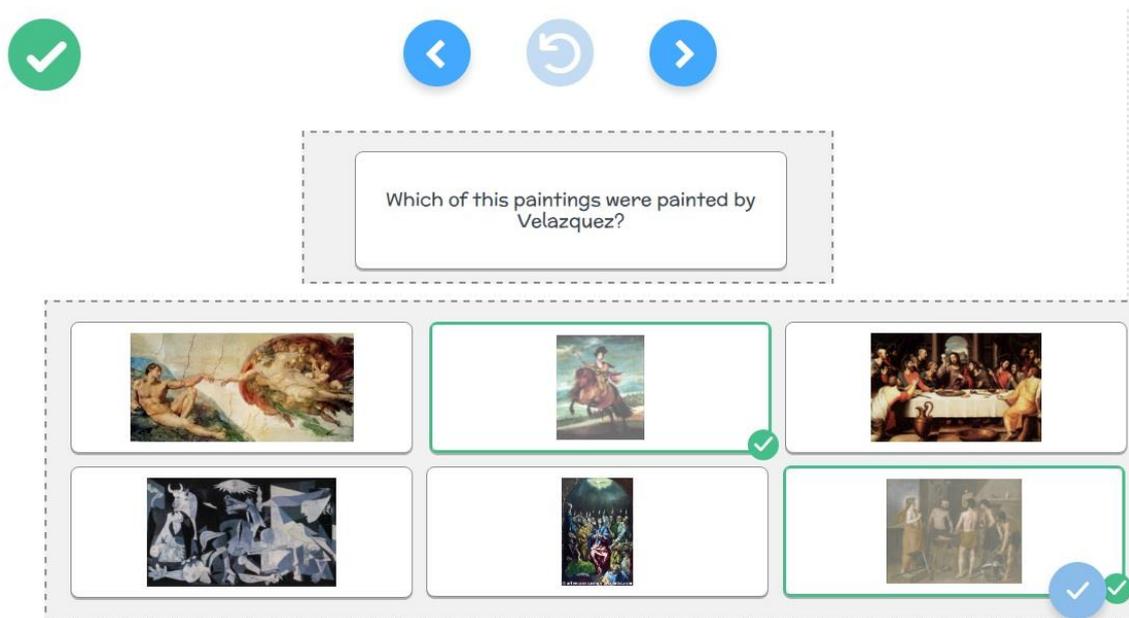
Figure 37. DEDOS-Web, Student's view, Delayed feedback

The next activity is the pair-matching activity shown in Figure 13. For this activity, the teacher has activated the option 'fail not allowed'; this will cause the activity to end immediately if the student fails, with no further chances to continue answering until the student completes all the goals. When this option is activated and the option 'right answer required' is not, if the user gives a wrong answer the activity will end and show the correct answers to the student. Figure 38 shows how the student has given a wrong answer, and therefore the activity ends while indicating the right answers with arrows. To represent the association made by the student, we use an icon with the same colour on the card moved by the user and the card where the user has dropped this card. The icon is located in the bottom left corner of the cards.

In the previous activity, one can observe that, even if the student has given a wrong answer, he/she cannot do the activity again. This possibility only exists if the option 'right answer required' is activated, which will require the student to give the right answer. Figure 39 shows what happens when this option is activated and the student does not complete an activity correctly. In this case, the button to restart the activity will be enabled, allowing the user to click it in order to do the activity again. Moreover, in this scenario DEDOS-Web will not show the correct answers, preventing the student from copying this answer once he/she restarts the activity.
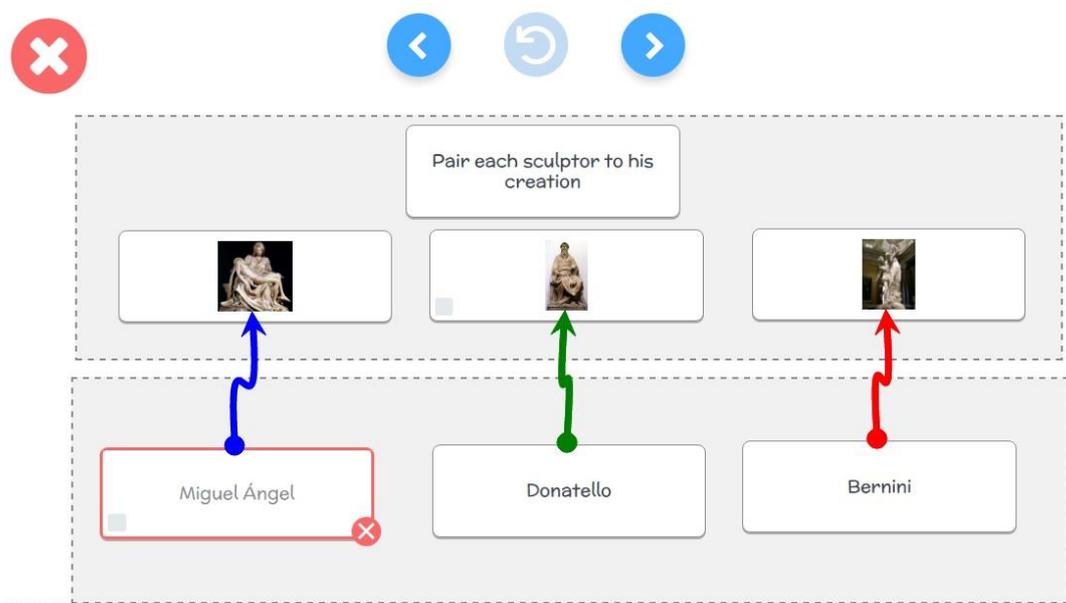
Figure 38. DEDOS-Web, Student's view, Fail not allowed
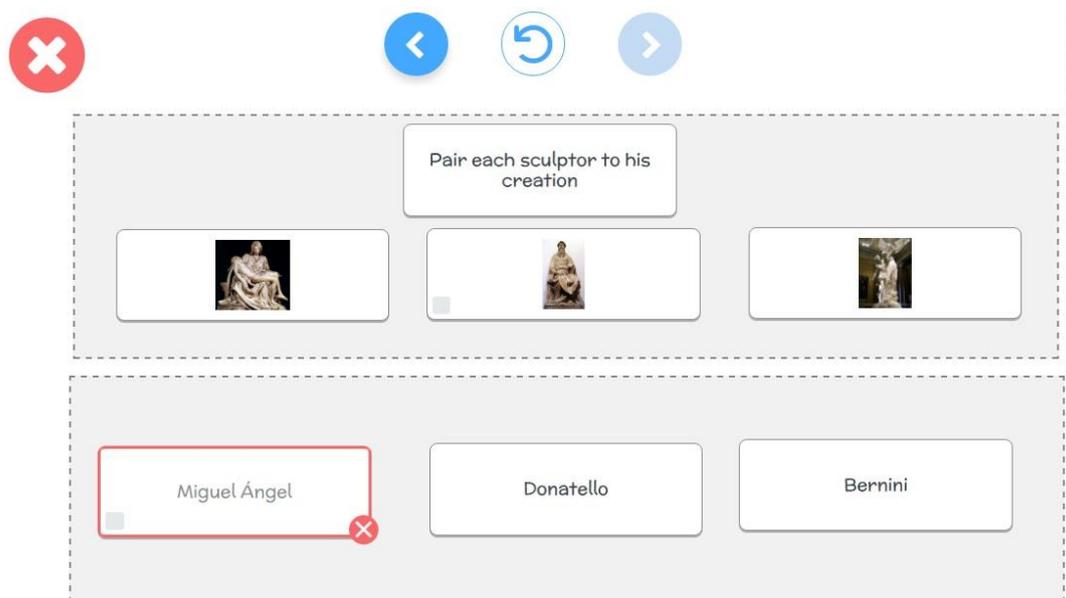
Figure 39. DEDOS-Web, Student's view, Right answer required

The last example corresponds to the addition activity designed in Figure 6. In this example, the option 'turns' has been activated. It has also been determined that the group will be made up of two students, and the groups will be generated dynamically. Moreover, the maximum wait time for the students to go to the next activity without having to wait for every member of the group to finish the activity is five minutes. Figure 40 shows that, once the groups are formed, one player has a turn to solve the activity (see the hand on the left side indicating whose turn it is); meanwhile, the other students have to wait until it is their turn to solve the activity (see the waiting symbol in the middle of the screen).
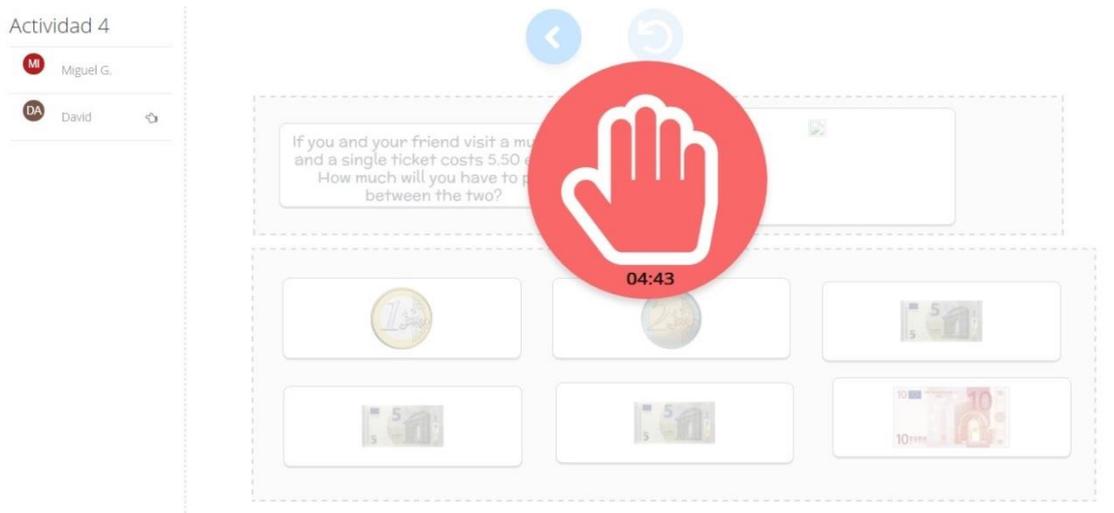
Figure 40. DEDOS-Web, Student's view, Turns

Once the activity is completed, the project will end and inform the user of this. If the teacher does not allow it, the student will not be able to do the project again. Therefore, if he/she tries to solve the activities again, DEDOS-Web will show a screen informing the student that this project has ended and cannot be repeated.

5.4 Data model

Figure 41 shows the general schema of the structure used to model DEDOS-Web and store the data in MongoDB. In this figure, we can observe that apart from saving a project and its activities, MongoDB also stores data about the users. There are two types of users in DEDOS-Web: teachers, who upload projects, create classrooms and add students; and players (students), who are added by a teacher and assigned to an educational project. This makes it possible to save the actions of each user, including the projects and classrooms assigned by the teacher as well as the players' interactions when solving the activities.

Figure 42 represents the overall schema of the database implemented in order to store all the data generated by DEDOS-Web. In 'projects', the projects uploaded by the teacher are stored. These projects are composed of 'activities', which have both cards ('elements') and goals ('objectives'). Users' information, both from teachers and players, is stored in 'users'. Regarding the students, the classrooms created by teachers are stored in 'classrooms'. Lastly, each student session is stored in 'sessions', and the activity answers are stored in 'answers'.

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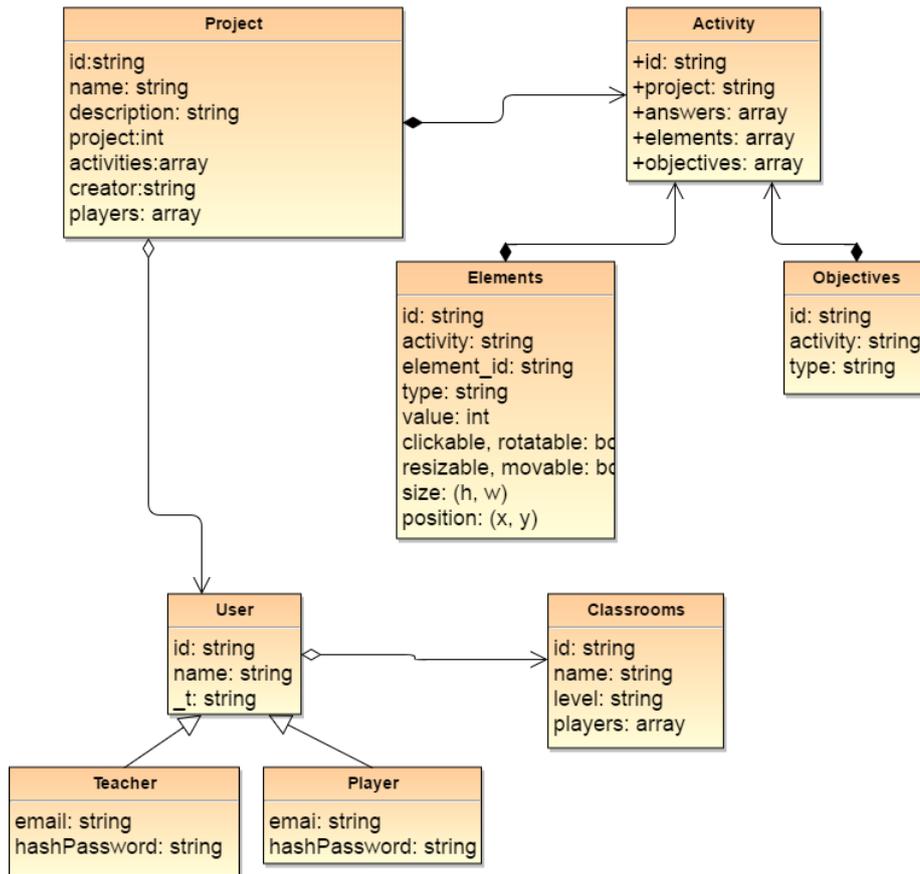
Figure 41. MongoDB, General schema of classes
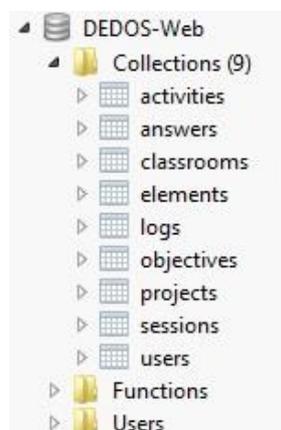
Figure 42. MongoDB, General schema of DEDOS-Web

Next, an explanation will be given regarding how users and classrooms are stored through MongoDB. Figure 43 shows a classroom stored in MongoDB. In this schema we can first observe the 'name' given to the classroom, along with the education level ('educationLevel'). In addition, teachers who are in charge of this classroom are stored in 'teachers', and the students are stored in 'players'.

Figure 43. MongoDB, Classroom

Both for teachers and students, MongoDB uses an identifier which refers to an object stored in the collection 'users', in which all the data regarding a specific user is stored. Figure 44 represents an example of a teacher's data where the stored information includes the name, the user and the encrypted password.

Thanks to the structure of MongoDB, which allows different data types to be stored in the same collections, it is possible to save other types of users with other properties in the same collection. This cannot be done in a relational database. Figure 45 shows an example of a student. For this type of user, teachers can define an avatar which will be an image. In case this property is empty, the avatar will be generated automatically by the application and created according the user's initials.

Figure 44. MongoDB, Teacher

Figure 45. MongoDB, Player

Figure 46 shows the database model of a project. Any elements stored in a MongoDB database are given an identifier ('_id') which can be used in other collections for cross-referencing; this will allow us to access all of the data on the referenced object at execution time. In addition, general information about the project is stored, such as the name, description, education level, identifier of the project, the route where the physical files are stored, the identifier of the user who uploaded the project, the creation date, the project resolution, the associated subjects and the project configuration. All of this information can vary as mentioned previously.

Figure 46. MongoDB, Project

Other details are stored for projects, such as the activities that comprise the project and the players associated with it. This includes saving each player's avatar (which can vary across projects), as well as an indication of whether they are connected and what their current status is (0 = not started, x = number of activity, -1 = finished).

Next, we present the model through which we store the data about the activities that make up an educational project. Figure 47 shows that every activity forms part of a project ('project') whose identifier ('_id') is stored in the activity model so that at all times the application knows which project it belongs to. In case the activity is done using turns, work groups will be created that will be stored in 'groups'. Moreover, within the activity (see Figure 48), the identifiers ('_id') of the elements ('elements') that form the activity are stored, as are the goals the players will have to achieve in order to finish it.

activities	Array [4]	Array
0	ObjectId("5768138755d446681b8620fd")	ObjectId
1	ObjectId("5768138755d446681b862108")	ObjectId
2	ObjectId("5768138755d446681b862114")	ObjectId
3	ObjectId("5768138755d446681b862121")	ObjectId
players	Array [6]	Array
0	{ 6 fields }	Object
avatar		String
user	ObjectId("5716413f2f591bd40c388940")	ObjectId
_id	ObjectId("576bbbbe5e07eff81dd9df99")	ObjectId
answers	Array [0]	Array
online	true	Boolean
status	4	Int32
1	{ 6 fields }	Object
2	{ 6 fields }	Object
3	{ 6 fields }	Object
4	{ 6 fields }	Object
5	{ 6 fields }	Object

Figure 47. Project, Activities and players

Figure 49 and Figure 50 show the information about a card that is stored in the collection 'elements'; this can be for a text card or an image card. The identifier of the activity the card belongs to is stored with the identifier of the card ('element_id'), which corresponds to the identifier that DEDOS-Editor has assigned to this card. In addition, the type of the card will be stored. Based on this, the card will have a variable where its text can be stored ('text') if it is a text card, or a list of images that will be stored in 'names'. Lastly, the features of the card will be stored ('clickable', 'rotatable', 'resizable', 'movable', 'feedback' and 'value'), as detailed in the third chapter of this document.

Figure 48. Activity

Figure 49. MongoDB, Card (text)

Figure 50. MongoDB, Card (image)

In the collection 'elements', the areas can also be stored (see Figure 51). This allows access to all the elements that comprise an activity in the same collection. As with cards, the identifier of the activity the area belongs to ('activity'), the identifier of the element assigned by DEDOS-Editor ('element_id') and the identifier of the cards that are contained in this area ('tokens') are all stored in an area.
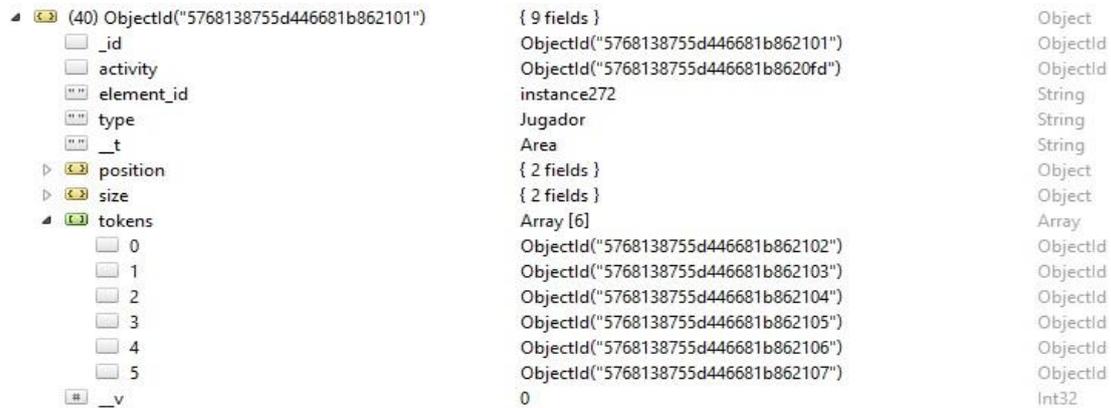
Figure 51. MongoDB, Area

Apart from the cards and the areas, an activity must also have one or several goals which are stored in the collection 'objectives'. Figure 52 shows an example of a multiple-choice goal, where the identifier of the activity it belongs to ('activity'), its 'type' and the card the player has to click to achieve this goal ('obj') are stored. Figure 53 shows a pair-matching goal, where 'targets' store the possible targets of the origin card ('origin'), while 'tokenMeter' is used to identify whether this pairing corresponds to an addition activity or if it is a normal association. The last type of goal is the addition goal (see Figure 54), which will store a numeric value the user must achieve to complete this goal ('numValue'), as well as the cards ('origTokens') and the origin areas ('origZones') that can be dragged and dropped onto the card with this goal.

Figure 52. MongoDB, Multiple-choice goal

Figure 53. MongoDB, Pair-matching goal

Figure 54. MongoDB, Addition goal

Lastly, it is necessary to store the answers of each of the students for each activity. This step is accomplished by using the collection 'answers' (see Figure 55). This collection creates a row for each player and activity, so that all the answers given by a single player in the same activity are stored in the same row. It may seem better to store this information in the project, but this would translate into more computational requirements when trying to retrieve information regarding one student in real time. Accordingly, knowing the project in this collection is not necessary. The player is identified through the 'player' property, where we stored an identifier of a row such as that explained in Figure 45. Moreover, the answers given by the player are stored in the array 'elements', where there will be one item for each answer given. Each answer stores information regarding the card the player has interacted with ('token'), whether or not the interaction resulted in the right answer ('valid'), and what type of interaction took place ('action'). The latter can be a selection action in a pair-matching activity, taking into account that addition activities are also solved by pairing cards. Moreover, the identifier of any goal that has been completed by this answer is stored. Lastly, in an answer we store the data related to an activity, such as its identifier, whether or not the activity has been 'finished', and whether or not the activity was completed correctly ('valid').

Figure 55. MongoDB, Answers

CHAPTER 6: DEDOS-EDITOR EVALUATION

As part of the evaluation of the work presented in this document, we first carried out a study aiming to show the importance of the learning curve in order to prevent rejection or abandonment of a tool provided to teachers, as well as how the paradigm used when designing content affects this curve. In this study, two interaction paradigms were analysed: the widespread menu-based interaction approach versus the direct manipulation paradigm used in DEDOS-Editor. We wanted to measure the intuitiveness, progression and retention (i.e. how easy is to remember how to use a tool after a period of non-use) of DEDOS-Editor. This study consisted of three sessions in which the participants had to design different types of educational activities. The following sections present the participants' characteristics, the methodology used, the measurement instruments and the results obtained.

6.1 Participants

The study was carried out with 42 students aged 21 to 30 years old who were pursuing degrees in Childhood Education and Primary Education at Universidad Rey Juan Carlos. Participation was voluntary and without economic compensation, although students earned ECTS credits according to the study duration. All the participants were familiar with JClic-Author, since this was used in the subject 'ICT in Education' to create educational projects. However, DEDOS-Editor was a new tool for all the participants. Due to this situation, we expected better performance with JClic-Author. We could therefore measure whether or not DEDOS-Editor was easy to learn, and whether the participants were able to achieve the same competences as with JClic-Author.

Participants were divided into two groups. One group started the study using JClic-Author and ended with DEDOS-Editor, while the second started with DEDOS-Editor and ended with JClic-Author. The participant distribution is shown in Table 2, including the number of participants that formed each group and the order in which the tools were used. The degree programmes the students belonged to were not taken into consideration, since the relevant subject matter was the same in both degrees.

Table 2. Participant distribution in DEDOS-Editor study

	Participants	Start	End
Group 1	24	JClic-Author	DEDOS-Editor
Group 2	18	DEDOS-Editor	JClic-Author

6.2 Methodology

Each participant had to design different educational activities in each of the three sessions. The first two sessions were carried out on the same day, and the participants came back two days after that to complete the third session. We decided to separate the third session in order to measure whether the participants were able to remember how to use the tool after a few days without using it. Information was provided gradually at the start of each session, and no additional information was given once the session started. After the three sessions, the participants completed a questionnaire so we could obtain their opinions about DEDOS-Editor and JClic-Author.

The educational activities to be designed were multiple-choice and pair-matching. The participants had to create each activity in less than five minutes. If the time ran out, participants could not finish the activity and had to advance to the next one. We decided to use this time limitation since it was twice the time needed by the developers to design the activities. The images that the students had to use to build the activities were given before starting the study so that they would not have to spend time searching for them.

First, participants were asked to design two multiple-choice activities with one tool, and then repeat this task with the other. As mentioned before, one group started with DEDOS-Editor and then used JClic-Author, and the other group did the opposite. Before participants began to design an activity, we showed them how the final result should look. Table 3 presents an example of the distribution of the activities the participants had to complete, along with the information provided at the start of each session.

The increasing difficulty of the activities made the participants think about the space distribution of the elements used, since the clarity with which content is shown can affect students' learning. The content of the activities for each of the tools was always the same. The study was focused on the most popular types of activities designed with JClic-Author, which were identified in a previous study (see Chapter 3, Section 3.1). The next sections describe each session in detail.

Table 3. DEDOS-Editor, Distribution of the activities to design per session

	Type	Session 1	Session 2	Session 3
DEDOS-Editor	Multiple-choice	2	2	2
	Pair-matching	2	2	2
JClic-Author	Multiple-choice	2	2	2
	Pair-matching	2	2	2
Information		No details	Interface explanation	Complete explanation

6.2.1 Session 1

No details were given about the tools in the first session, other than where to find the main menus and elements. The first two activities in this session were multiple-choice activities consisting of a text area stating the problem and three choices with only one correct answer. In the first activity, under the question 'Which of these animals lays eggs?', three graphical choices were to be shown using images of a gorilla, an elephant and a turtle. In the second activity, under the question 'Which of these countries does not belong to the European Union?', three text choices had to be provided for Canada, Germany and Spain. Figure 56 shows the first multiple-choice activity designed with DEDOS-Editor.

Next, the participants had to design the same activities with JClic-Author. In JClic-Author, multiple-choice activities are called 'identification activities'. The first step is to find and select this type of activity in an initial menu. Then, in the 'Panel' tab, users can set the number of desired answers and choose how they will appear (one row and three columns, in this case) to create an activity with a similar look and feel to that designed with the other tool. This process creates a matrix that can be filled cell by cell by adding the appropriate images and setting the correct answer in the 'Relations' tab. Finally, the question statement has to be set in the 'Messages' tab. An example of the result can be seen in Figure 57. As with DEDOS-Editor, JClic-Author allows the user to add text to the cells instead of images, which can be used to create the second multiple-choice activity.
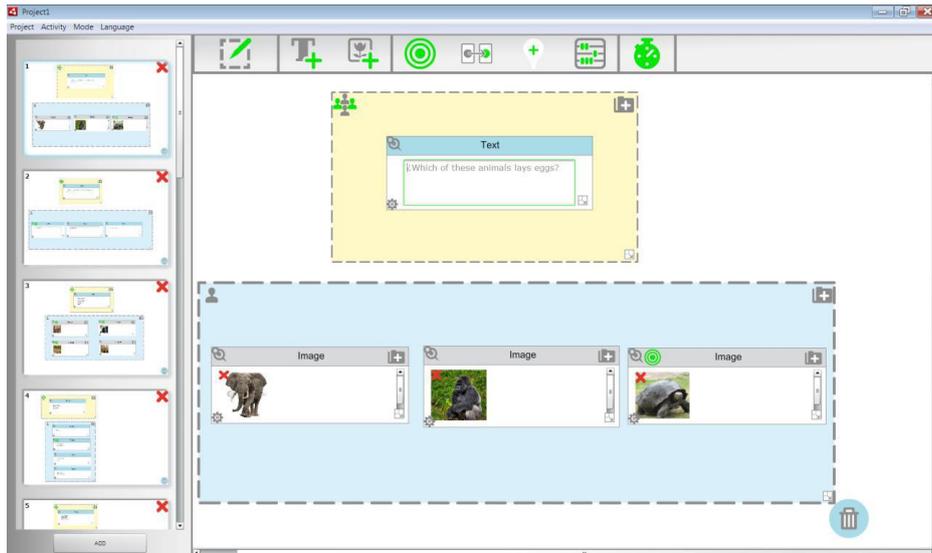
Figure 56. Session 1, DEDOS-Editor, First multiple-choice activity
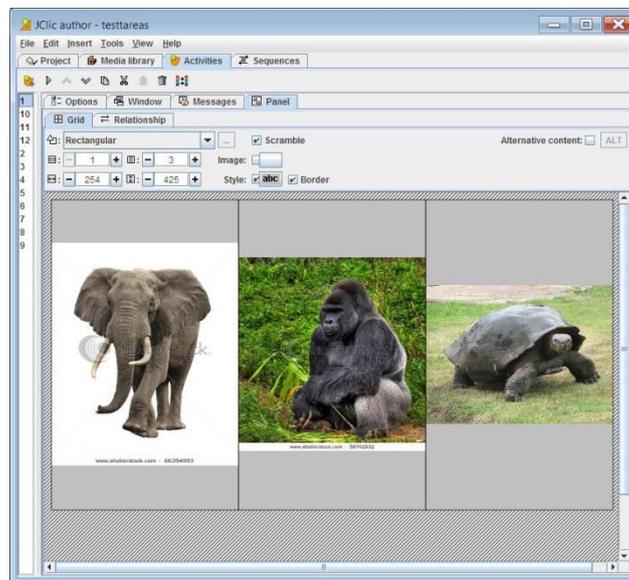
Figure 57. Session 1, JClic-Author, First multiple-choice activity

The two pair-matching activities in the second session entailed an image-to-image activity to associate three types of products with a corresponding recycling bin, and an image-to-text activity to associate three characters with their corresponding professions. In DEDOS-Editor, participants again have to drag a game zone and a player zone into the editing panel. In the game zone, they must add the statement and the three tokens that will be used as the destination of the tokens placed in the player zone. Participants must then place a pair-matching icon on each of the tokens and move the arrow that appears over the element intended for pairing. As with multiple-choice activities, participants can use either text or image tokens interchangeably. Figure 58 presents a recreation of one of the

pair-matching activities designed with DEDOS-Editor, where the relationships are visually represented by arrows between two cards.
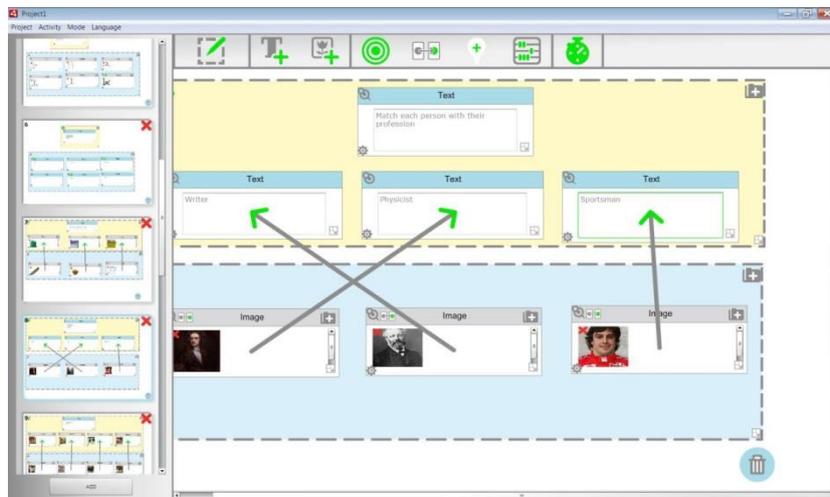
Figure 58. Session 1, DEDOS-Editor, First pair-matching activity

In JClic-Author, these types of activities are called 'complex association'. Participants must identify and find this type of activity in the initial menu in order to start the activity's construction. Then, participants need to set up the number of elements of the relations in the 'Panel' tab, and choose the position of each cell as well as the images or text they should contain. JClic-Author automatically creates a relation between each cell and the one above it, which can be changed in the 'Relations' tab. However, this process turns out to be non-trivial for many participants because the relationships between the different elements of the activity are not clear in the interface (see Figure 59).
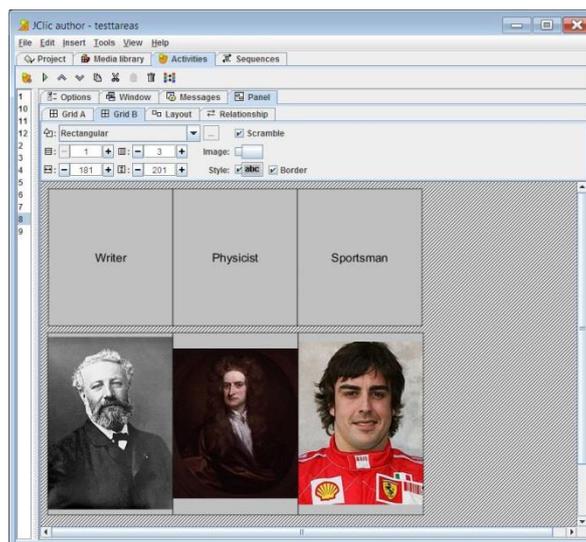
Figure 59. Session 1, JClic-Author, First pair-matching activity

6.2.2 Session 2

Activities in this session were slightly more difficult, and included more tokens in play as well as more multiple-choice targets. However, participants were given more details about the user interfaces. In the case of DEDOS-Editor, 'zone', 'token', and 'target' concepts were explained, while for JClic-Author, participants were shown how to create activities, use messages and panels, and set up targets in the 'Relations' tab. After the explanations, we repeated the same methodology used in Session 1 to design two multiple-choice and two pair-matching activities with both tools.

In the first multiple-choice activity, we increased the number of tokens, images, and targets; this was done so that the user had to discover that several images can be added to the same element, and that the same activity can have more than one correct answer. The second multiple-choice activity required participants to use a different layout with a single column of options instead of the 2x2 matrix used in the previous activity. As in Session 1, these activities had to be created with both DEDOS-Editor and JClic-Author. In the pair-matching activities, the number of tokens on screen was incrementally increased in order to force participants to manage the available space and adjust the zones and card sizes appropriately. There were also more elements than the first session in this case. In pair-matching activities, each new association resulted in two new cards in DEDOS-Editor, which clearly reduced the available space. In JClic-Author, this scenario was managed by changing the matrix layout used in the activity.

6.2.3 Session 3

Session 3 started with a full explanation of both tools, including how to take advantage of Windows Explorer thumbnails for easy location, along with several detailed examples of solving the activities from previous sessions. This provided participants with the full information needed to create activities in a timely manner and to make the most of both applications. Each participant had to design two multiple-choice activities and two pair-matching activities, using both DEDOS-Editor and JClic-Author. To analyse the skills acquired with both tools, these activities included text and image tokens, multiple-choice activities with single and multiple goals, and a varied number of tokens in play.

6.3 Measurement instruments

One of the key points of the experimental study is the lack of information that forces users to experiment with the tool to discover its uses and possibilities. Gradually increasing the complexity also allows us to analyse how previously acquired knowledge helps the user when progressing to more complicated tasks. These factors enable us to evaluate the learning curve regarding the entry point, learning evolution, and competence acquired. We consider the entry point as the difficulty the user encounters when using a tool for the first time with little or no knowledge; this is represented by the completion rate of the first activity in Session 1. The learning evolution is the rate at which users acquire skills throughout use, which is represented by the slope of the completion rate curve as a user gradually masters tool activities. Finally, the acquired competence is the level of mastery a user can reach after fair use of the tool; this is represented by the last point on the completion rate curve from the last activity.

Since all these factors strongly depend on the students' experience and competence in using computers and educational software, we analysed the results by dividing participants into two groups according to their performance in the last session. We assume that the computer skills did not vary throughout the experimental study, and thus consider the last session as a proper proxy for this competence. It is worth noting that data related to the user profile (e.g. course or age) did not provide any meaningful segmentation of the population.

We used the k-means method to make this division, where the objective is to divide N observations into X clusters in which each observation belongs to the cluster closest to its mean. With this method, users were divided into novices (15 participants, M=165.5 s) and experts (27 participants, M=111.5 s).[2] A chi-square test of independence was used to determine whether the order in which participants performed the experimental study affected the clustering (see Groups 1 and 2 in Table 4). The relation between these variables was not significant ($X2$ (1, N=42) = 0.08, p=0.78; see Table 4). Thus, the participant allocation did not interfere with the students' performance. Using this segmentation, we analysed the evolution of novice and expert users with both tools, and compared their entry points, learning curves, and competencies acquired.

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[2] M is the mean time to complete an activity (measured in seconds) for each group considering only the activities in the last session.

Table 4. Distribution of participants in groups

	Participant distribution		
Cluster	**Group 1**	**Group 2**	**Total**
Novices	9	6	15
Experts	15	12	27
Total	24	18	42
X^2		=	0.08
p = 0.78			

6.4 Results

This section presents the data obtained from the analysis of the completion rate of the activities designed by the participants, along with the evaluation given by these participants in the satisfaction questionnaire they filled out at the end of the study.

6.4.1 Analysis of the completion rate

In analysing the results of the sessions, we paid special attention to the completion rate of activities as a correlate of intuitiveness and ease of use by comparing the number of participants who finished each task for each tool in each session. We considered a task to be complete if the activity was designed correctly, or if the final result was equivalent to that requested in less than five minutes. Sometimes, the same activity can be designed in different ways with both tools. We used McNemar's test to compare the completion rate proportions for each tool. This test checks the equality of proportions using the within-subject design of the experimental study. In subsequent figures and tables, we use the abbreviation 'Sel' to refer to multiple-choice activities, and the abbreviation 'Emp' to refer to pair-matching activities.

6.4.1.1 Novice – Multiple-choice activities

As expected, we observed a steady increase in the completion rates of novice users in multiple-choice activities throughout the sessions, which resulted from gaining familiarity through use. Although not statistically significant, the completion rate was higher with DEDOS-Editor than with JClic-Author. However, we found a discrepancy in the first multiple-choice activity in the third session, where the completion rate was much

lower. This was a multiple-choice activity similar to those designed in the first and second sessions. We believe that the low rate was caused by poor retention of the JClic-Author interface, due to the many menus that the user has to memorise in order to use the tool well. This factor made the participants underperform in this activity, thus producing a considerable drop in the completion rate. The results can be seen in Figure 60 and Table 5.
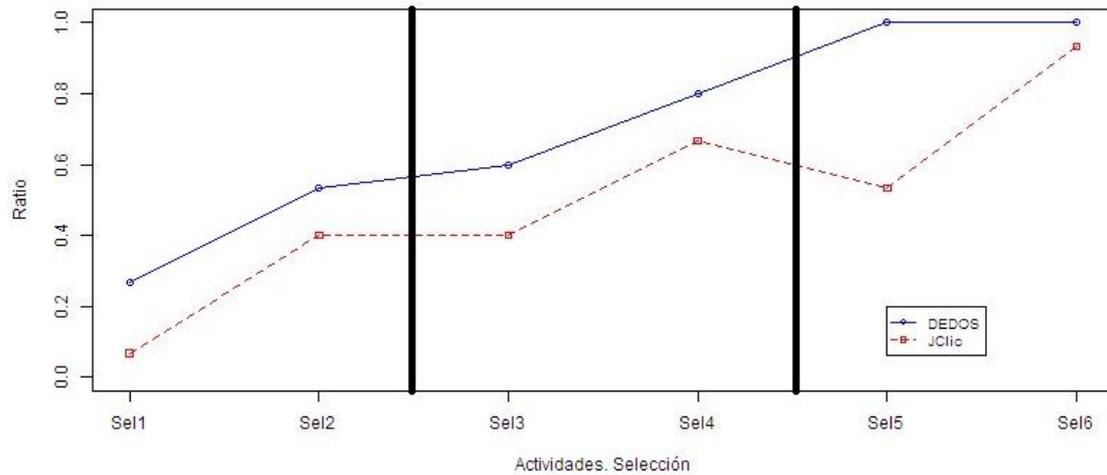
Figure 60. Novice group, Completion rate of multiple-choice activities

The table shows the number of participants who finished the corresponding activities within the given time. Moreover, it is possible to distinguish which participants ended the activity with DEDOS-Editor, JClic-Author, both applications or neither. For instance, 10 participants from the novice group did not finish the first multiple-choice activity with either of the tools, only one participant completed the activity with JClic-Author only, and four participants completed the activity with DEDOS-Editor only.

Table 5. Novice group, Completion rate of multiple-choice activities

		DEDOS-Editor					
		NO		YES			
Activity		JClic-Author		JClic-Author		X^2	**p value**
		NO	YES	NO	YES		
Ses1	Sel1	66.67% (10)	6.67% (1)	26.67% (4)	0.00% (0)	1.8	.179
	Sel2	33.33% (5)	13.33% (2)	26.67% (4)	26.67% (4)	0.67	.414
Ses2	Sel3	33.33% (5)	6.67% (1)	26.67% (4)	33.33% (5)	1.8	.179
	Sel4	13.33% (2)	6.67% (1)	20.00% (3)	60.00% (9)	1	.317

Ses3	Sel5	0.00% (0)	0.00% (0)	46.67% (7)	53.33% (8)	7	**.008****
	Sel6	0.00% (0)	0.00% (0)	6.67% (1)	93.33% (14)	1	.317

6.4.1.2 Experts – Multiple-choice activities

Expert users show a higher entry point than novices (37% and 25.9% in DEDOS-Editor, compared to 26.4% and 6.7% in JClic-Author, respectively), followed by a stronger increase in the completion rate which remained above 75% for both tools throughout the remainder of the experimental study. DEDOS-Editor seems to have higher completion rates for all activities except the second, although there is no statistical significance. Nevertheless, it is important to remember that DEDOS-Editor had not been previously used by any participants, whereas all participants had used JClic-Author during their degree coursework.

The activity with the smallest p-value was Sel3 (p=0.025),[3] in which users finished about 20% more activities with DEDOS-Editor than with JClic-Author. This reaffirms our thoughts regarding retention for the JClic-Author interface when analysing the results of novice participants. Considering that users fall into the expert category, both learning curves are quite satisfactory with a reasonably high entry point, fast achievement of competence, and full competence acquired. The results can be seen in Figure 61 and Table 6.
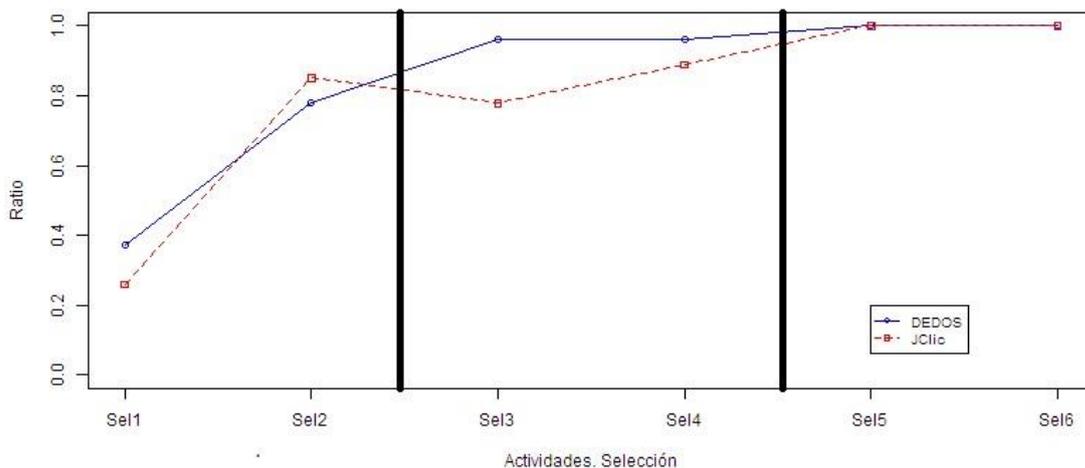
Figure 61. Expert group, Completion rate of multiple-choice activities

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[3] After applying Bonferroni correction, the corrected p-value of Sel5 (.025*6=0.15) is greater than the 5% significance level.

Table 6. Expert group, Completion rate of multiple-choice activities

Activity		DEDOS-Editor				X^2	p value
		NO		YES			
		JClic-Author		JClic-Author			
		NO	YES	NO	YES		
Ses1	Sel1	51.85% (14)	11.11% (3)	22.22% (6)	14.81% (4)	1	.317
	Sel2	7.41% (2)	14.81% (4)	7.41% (2)	70.37% (19)	0.67	.414
Ses2	Sel3	3.70% (1)	0.00% (0)	18.52% (5)	77.78% (21)	5	.025
	Sel4	3.70% (1)	0.00% (0)	7.41% (2)	88.89% (24)	2	.157
Ses3	Sel5	0.00% (0)	0.00% (0)	0.00% (0)	100% (27)	-	-
	Sel6	0.00% (0)	0.00% (0)	0.00% (0)	100% (27)	-	-

6.4.1.2 Novices – Pair-matching activities

Pair-matching activities proved to be more difficult than the multiple-choice activities. In addition, throughout the experimental study, we found that the amount of time users spent on finding and adding images to the tokens or cells was significantly large compared to the total amount of time spent on finishing the tasks. Users had to insert six to ten different images into the activity, and given the five-minute limitation, those who did not add the images fast enough tended to run out of time before completing the task.

The learning curves for DEDOS-Editor and JClic-Author are significantly different in this case (see Figure 62). DEDOS-Editor had a higher entry point than JClic-Author, and this entry point is higher than that of novice users doing multiple-choice activities using DEDOS-Editor. This can be explained by the fixed creation paradigm of DEDOS-Editor, in that the experience users acquired by doing the multiple-choice activities in Session 1 served as an entry point for the pair-matching activities. In the second activity, the completion rate increased to 73.3%. In contrast, with JClic-Author, less than 10% of users were able to finish the pair-matching activities in Session 1 despite more than 50% having finished the multiple-choice activities. This happened because designing multiple-choice activities and pair-matching activities is fundamentally different in JClic-Author, so the experience acquired in designing the former cannot be exploited in the latter. In addition, finding the right template to begin with is not very

intuitive, and participants had serious problems with choosing the correct type of activity from the initial menu. Surprisingly, this low rate did not improve until the end of Session 2, despite users being explicitly told which type of activity they had to choose at the beginning of the session. Overall, DEDOS-Editor shows a higher entry point followed by an immediate increase in completion rates, while JClic-Author shows a flat curve that remained close to 0 until half the experimental study was completed.
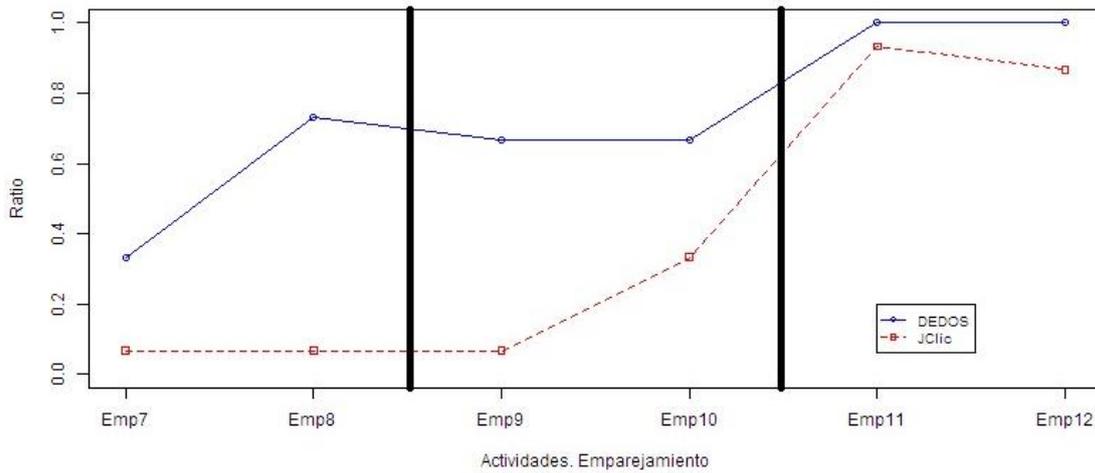
Figure 62. Novice group, Completion rate of pair-matching activities

In the second session with DEDOS-Editor, there was a slight decrease in the number of finished tasks. Since the first and second sessions were performed on the same day, we believe this was caused by the large amount of images the participants had to add in Session 2, rather than by users forgetting how to use the tool. The results are summarised in Table 7. It is worth noting that Emp8 and Emp9 are statistically significant, even after considering Bonferroni correction for multiple comparisons.

Table 7. Novice group, Completion rate of pair-matching activities

		DEDOS-Editor					
		NO		YES			
	Activity	JClic-Author		JClic-Author		X^2	*p* value
		NO	YES	NO	YES		
Ses1	Emp7	60.00% (9)	6.67% (1)	33.33% (5)	0.00% (0)	2.67	.102
	Emp8	26.67% (4)	0.00% (0)	66.67% (10)	6.67% (1)	10	**.001****

Ses2	Emp9	33.33% (5)	0.00% (0)	60.00% (9)	6.67% (1)	9	**.002****
	Emp10	26.67% (4)	6.67% (1)	40.00% (6)	26.67% (4)	3.57	.058
Ses3	Emp11	0.00% (0)	0.00% (0)	6.67% (1)	93.33% (14)	1	.317
	Emp12	0.00% (0)	0.00% (0)	13.33% (2)	86.67% (13)	2	.157

6.4.1.2 Experts – Pair-matching activities

The analysis of expert users with pair-matching activities shows a remarkable difference in entry points (see Figure 63). The completion rates differ by one order of magnitude for the first activity of Session 1 (74.1% with DEDOS-Editor, 7.4% with JClic-Author); this has special significance when considering that most participants had previous experience with JClic-Author, while none had any familiarity with DEDOS-Editor. As shown in Table 8, these significant differences between tools are visible during the first two sessions. Although applying the Bonferroni adjustment to Emp7, Emp8 and Emp10 causes them not to be statistically significant, along with Emp9 they constitute more than half of the remaining tests which showed a real effect.
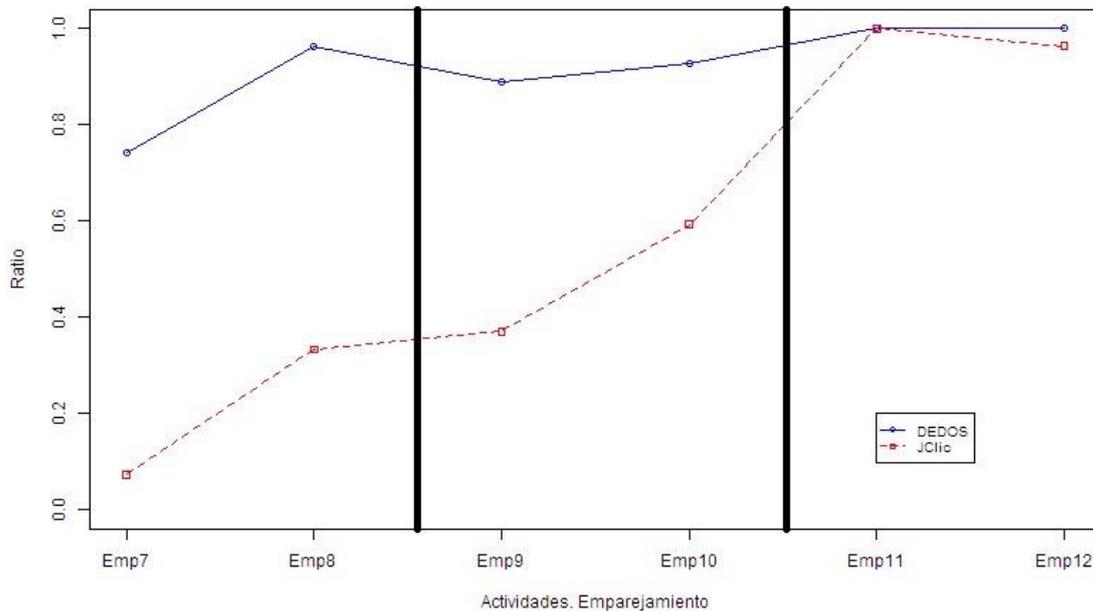
Figure 63. Expert group, Completion rate of pair-matching activities.

In this case, it seems that students need the full explanation for JClic-Author in order to create pair-matching activities. Two factors can explain these results. First, the DEDOS-Editor user interface is based on a direct manipulation paradigm that avoids

menus, right clicks, and other commonly used computer paradigms in favour of a more direct and visual representation of options and actions. With this paradigm, intuitiveness plays a very important role in facing unknown situations, so that solutions can be constructed by instinct without the proper knowledge or specific training. Second, the DEDOS-Editor user interface is designed as a holistic experience in which all possible designs emanate from common principles. There is no single choice that can constrain the possibilities of a future design, and every new type of design requires only a small amount of new concepts. This allows users to take advantage of a variety of common concepts used in every possible design. Therefore, completion rates were similar between the first instances of designing both pair-matching activities and multiple-choice activities with JClic-Author. In contrast, DEDOS-Editor users showed similar completion rates to the last time they designed multiple-choice activities, since they could use all the knowledge and experience gained in designing one type of activity when facing a new type of challenge.

Table 8. Expert group, Completion rate of pair-matching activities

Activity		DEDOS-Editor				X^2	*p* value
		NO		YES			
		JClic-Author		JClic-Author			
		NO	YES	NO	YES		
Ses1	Emp7	25.93% (7)	0.00% (0)	66.67% (18)	7.41% (2)	18	**.015***
	Emp8	3.70% (1)	0.00% (0)	62.96% (17)	33.33% (9)	17	**.025***
Ses2	Emp9	11.11% (3)	0.00% (0)	51.85% (14)	37.04% (10)	14	**<.001*****
	Emp10	0.00% (0)	7,41% (2)	40.74% (11)	51.85% (14)	6.23	**.012***
Ses3	Emp11	0.00% (0)	0.00% (0)	0.00% (0)	100% (27)	-	-
	Emp12	0.00% (0)	0.00% (0)	3.7% (1)	96.3% (26)	1	0.317

Besides the difference in entry points, users display a satisfactory upward learning curve with both tools. In the case of DEDOS-Editor, we observed a slight drop in completion rate at the beginning of Session 2 due to the increased number of images participants had to add; nevertheless, the rate returned to 100% once users mastered image insertion. In JClic-Author, completion rates do not exceed 75% until the last session due to the extremely low entry point, despite the monotonic growth of the learning curves.

6.4.2 Questionnaire analysis

At the end of the study, participants had to fill out a usefulness, satisfaction and ease of use questionnaire for both DEDOS-Editor and JClic-Author. They were asked questions regarding utility, ease of use, ease of learning and satisfaction, so that we could compare both tools. Figure 64 shows the average results for each section. Overall, DEDOS-Editor received a better score in all sections; this is an encouraging result for our research, in which the design of an intuitive interface prevailed over designing a tool with high functionality but low usability. The latter is one of the main problems of current authoring tools, as we saw with JClic-Author, a tool which offers a great deal of variety regarding activity creation, but is difficult to begin working with without proper training or knowledge of the tool.
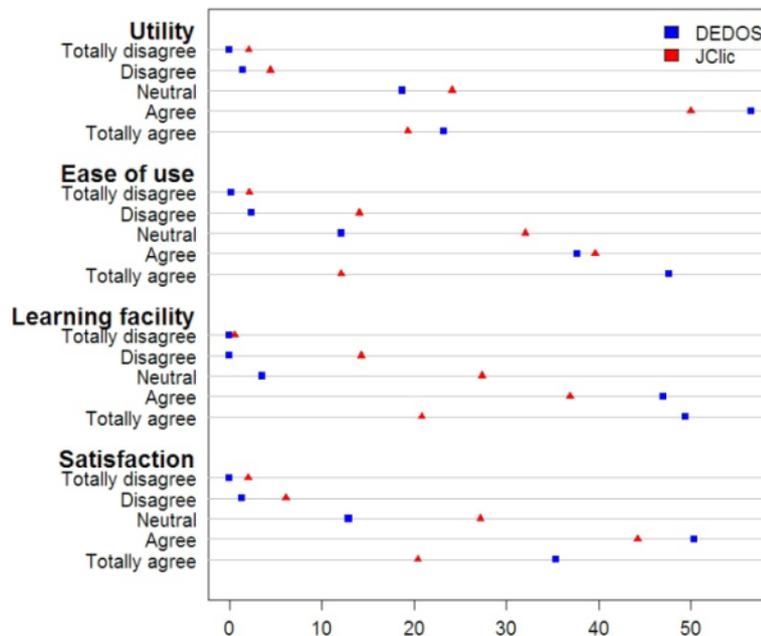
Figure 64. Satisfaction questionnaire results

The users considered DEDOS-Editor to be a useful tool (56.5% agreed and 23.2% totally agreed). On the other hand, 50% of the participants agreed that JClic-Author was useful and 23.2% totally agreed. It is interesting to point that when asking to participants whether these tools allowed them to save time when designing their educational activities, the mean score for DEDOS-Editor was 4.25, while for JClic-Author it was only 3.60. It is key that teachers spend all their time on creating their educational projects rather than on learning how to use the tool properly.

A total of 47.6% of the participants remarked that DEDOS-Editor was easy to use, while only 12.1% had the same thoughts about JClic-Author. When reviewing the results of the ease of use section, we discovered that students were able to use DEDOS-Editor without written instructions (4.38 out of 5), despite the fact that it was a tool they were using for the first time. Meanwhile, JClic-Author only achieved a score of 3.26 out of 5 for this query. Furthermore, the participants again noted the minimal effort required to use DEDOS-Editor without previous knowledge (4.38 out of 5), while they struggled when using JClic-Author (3.35 out of 5).

Moreover, no one commented that DEDOS-Editor was difficult to learn; this was because the knowledge acquired when designing one activity could be used when designing another type of activity, as mentioned above. The opposite happened with JClic-Author: 25 participants had a bad experience when using it, because the options offered were different for each type of activity. Overall, DEDOS-Editor obtained a mean score of 4.45 in the ease of learning section, while JClic-Author achieved a 3.63 score: a difference of 0.8 points. The participants confirmed the results obtained in (Roldán-Álvarez et al., 2016). Although DEDOS-Editor is a new authoring tool, it allows users to quickly learn how to perform tasks with it, and therefore they do not get frustrated when first using it. This helps when adopting a new tool, since users usually prefer those which do not require a long period of training or familiarisation. Not having to learn the functionality of an authoring tool when resuming its use after a period of inactivity is also a key factor for adopting a certain tool. As the participants indicated, DEDOS-Editor is a tool whose use is remembered easily (4.57). Regarding JClic-Author, students did not feel the same and gave it a lower score (3.5).

In summary, over 85% of the participants were satisfied with DEDOS-Editor, even though it is a very new tool which they had not seen before, meaning that they had no previous experience with it. On the other hand, only 60% of the participants said that JClic-Author was satisfactory. Most of the participants indicated that DEDOS-Editor was an interesting tool to use (4.25 score), while JClic-Author obtained a lower score in this section (3.52). These scores show how important it is to design an application properly in order to improve the user's experience and make them embrace the application in their workplaces.

In order to verify whether the results obtained were statistically significant, we performed a test comparing the overall results obtained from the questionnaires for both

tools. Since each question from the test could be answered with a value from 1 to 5, and because there were a total of 30 questions, each participant could give scores from 30 to 150 for both DEDOS-Editor and JClic-Author (each participant answered both questionnaires). DEDOS-Editor scores followed a Gaussian distribution, but JClic-Author scores did not. Therefore, we decided to transform the ranks to z-scores, creating Gaussian distributions which would allow us do the T-Student test. After performing this test, we determined that there was statistical significance among the results gathered ($t=4.82$, $df=81.84$, $p<0.05$). This led us to think that DEDOS-Editor fulfilled participants' expectations.

In addition, we asked the participants about the strengths and weaknesses of DEDOS-Editor in order to improve the tool in the future. Again, participants highlighted the tool's ease of use, since 32 out of 48 said DEDOS-Editor was easier to use than JClic-Author. When discussing weaknesses, they mostly pointed out functionality problems such as: bad positioning of the bin, which was on the right side of the editing area, causing the participants to delete the elements unintentionally when resizing them; (11 out of 48) and the lack of activity types compared to JClic-Author (10 out of 48). Regarding the latter, when this experiment was developed, DEDOS-Editor only had two types of activities – selection and pair-matching – since these were the most popular activities for teachers when designing educational projects. After this study, we decided to add math activities and connect the dots activities, which complemented the set of activities offered in DEDOS-Editor.

To verify the findings of this study after applying the improvements mentioned in the above paragraph, we performed another similar trial. In this study, 64 participants aged 20 to 50 years old with varied backgrounds (students from various degrees, as well as teachers and researchers) had to design activities with DEDOS-Editor only. Once the course ended, they had to evaluate DEDOS-Editor by filling out a satisfaction questionnaire.

In this case, 64.3% of the participants thought that DEDOS-Editor was a useful tool (43.1% agreed and 21.2% totally agreed). Regarding the ease of use, a total of 72.3% of the participants felt that DEDOS-Editor posed no impediment to using it (39.5% agreed and 32.8% totally agreed). Moreover, 89.0% of the participants stated that it was easy to quickly learn how to use DEDOS-Editor and remember its mechanics after a period of disuse (35.9% agreed and 53.1% totally agreed). Finally, a total of 83.7% of the

participants were satisfied with the tool (38.2% agreed and 45.5% totally agreed). The results of this questionnaire are summarised in Table 9. To understand this table, we must take into account that each section had a different number of questions. The utility section had a total of seven questions, ease of use had a total of seven questions, ease of learning had a total of three questions, and satisfaction had a total of three questions. Each of the columns represents the score given for the questions from a certain section, with 1 indicated strongly disagree and 5 indicating strongly agree. For example, in the utility section, from the 64 students who answered the questionnaire (64 students multiplied by the seven answers in the utility section = 448 total answers), they gave a score of 1 out of 5 seven times.

Table 9. Second study, Satisfaction questionnaire results

	1	**2**	**3**	**4**	**5**
Utility	1.5%	6.3%	27.9%	43.1%	21.2%
E. of Use	1.1%	5.1%	21.5%	39.5%	32.8%
E. of Learning	0.0%	2.6%	8.4%	35.9%	53.1%
Satisfaction	0.0%	2.6%	13.7%	38.2%	45.5%

DEDOS-Editor was also used by another 40 future teachers. In the experiment, they learned how to create educational activities with this tool. Once the experiment ended, we asked them a few questions about the use of the tool and the experiment itself. Table 10 shows the results of the questionnaire, in which the teachers had to give a score from 1 (strongly disagree) to 5 (strongly agree). Yet again, the answers given by the teachers show that DEDOS-Editor is a tool that is easy to learn, and that enables teachers to enhance their creativity in order to give their students motivating content that allows them to have fun while learning.

Table 10. Questionnaire about the use of DEDOS-Editor in real learning environments

	1	**2**	**3**	**4**	**5**
DEDOS-Editor is easy to learn	0%	0%	6.8%	31.8%	61.4%
DEDOS-Editor should be included in teachers' training programmes	0%	2.3%	6.8%	36.4%	54.5%
I enjoyed the use of DEDOS-Editor	0%	2.3%	13.6%	38.6%	45.5%
I have learned to use DEDOS-Editor	0%	0%	6.8%	31.8%	61.4%

	1	2	3	4	5
efficiently					
DEDOS-Editor increases my creativity	0%	0%	2.3%	36.4%	61.4%
The use of technology motivated my students	0%	2.3%	6.8%	40.9%	50%

Finally, 10 teachers (four childhood teachers, three primary school teachers and one special needs teacher) who currently use DEDOS-Editor in their classrooms answered a questionnaire about their daily use of technology in the classroom, specifically regarding the use of DEDOS-Editor. The results are summarised in Table 11 and Table 12.

Table 11. Availability of technological resources according to in-service teachers

	1	2	3	4	5
Hardware is located in an appropriate place	0%	20%	30%	30%	20%
The school has enough computers, tablets or digital blackboards for the students	30%	30%	20%	20%	0%
The school has appropriate software for the students	20%	40%	20%	20%	0%
The school gives enough technological support for teachers	10%	20%	40%	30%	0%
Technology gives additional value to traditional learning methods	0%	0%	0%	40%	50%
Technology interferes with learning	60%	20%	10%	10%	0%
I can find appropriate applications for my students	0%	30%	20%	30%	20%
The use of technology motivates the students	0%	0%	0%	40%	60%

Although most of the teachers find that technology can be useful in learning scenarios since it motivates the students and can add value to traditional learning methods, therefore not interfering with the learning itself, schools do not always offer the appropriate support for the teachers (in terms of hardware and software) to fully implement the use of technology on a daily basis.

Table 12. Questionnaire about the use of DEDOS-Editor by in-service teachers

	1	2	3	4	5

I use the app to introduce new ideas	0%	10%	10%	60%	20%
Students use this app to practice concepts	0%	10%	20%	50%	20%
Learning content is related to the concepts explained in class	0%	0%	10%	50%	40%
The app seems friendly	0%	0%	10%	40%	50%
The app is easy to install	0%	0%	0%	20%	80%
It is possible to adapt the difficulty of the activities	0%	0%	20%	20%	60%
Students can start the app without help	0%	0%	20%	50%	30%
Students can use the app without help	0%	0%	30%	50%	20%
The students enjoy using the app	0%	0%	0%	60%	40%
Individual results of each student are available for the teachers	0%	0%	30%	40%	30%
I need help frequently when using the app	60%	20%	0%	10%	10%
There are problems with the app that I cannot resolve myself	30%	30%	10%	20%	10%

In this case, DEDOS-Editor also seems to be appropriate for use in the classroom. Teachers highlighted how easy it is to install DEDOS-Editor and to start using it in the classroom. Moreover, teachers can use the application with no help and can resolve the problems that arise on their own. They stated that even the students can use the application with any help, and that they enjoy performing the activities designed by their teachers.

6.5. Discussion

Through the comparative study of DEDOS-Editor and JClic-Author, we expected to shed light on those factors which could be important for teachers to use authoring tools properly in order to create digital content. Both tools were designed with the intention of helping teachers in the creation process. However, it seems that there are some factors which prevent the complete adoption of content creation technology.

Figure 65 shows the general results of this study, dividing each session by vertical lines. In general, participants were able to complete a greater percentage of activities with DEDOS-Editor than with JClic-Author. This percentage increased for both tools through

their use and training, showing that participants learned throughout the study. Furthermore, it can be observed that the entry point for both tools was below 40%, and the completion rate increased towards 100% for DEDOS-Editor; JClic-Author was near this percentage. It is important that we did not provide any kind of mentoring with DEDOS-Editor at the beginning of the experimental study, even though this is highly advisable in order to improve teacher acceptance and knowledge when encountering an authoring tool for the first time (Boulay et al., 2009). However, the students in our study should have full knowledge of JClic-Author and a positive attitude towards this tool since learning it is part of their degree. According to Kopcha (2012), the participants should be more skilled with JClic-Author since they have had previous access to it, and because most had used it in real classrooms during their internship placements. Nevertheless, our experimental data shows that having previous knowledge of a certain tool does not guarantee proper use of it in the future, which could prevent full adoption (Aldunate et al., 2013; Blackwell et al., 2013). Quantitative data verified the results obtained in the satisfaction questionnaire, which indicated that many participants had trouble when using JClic-Author.
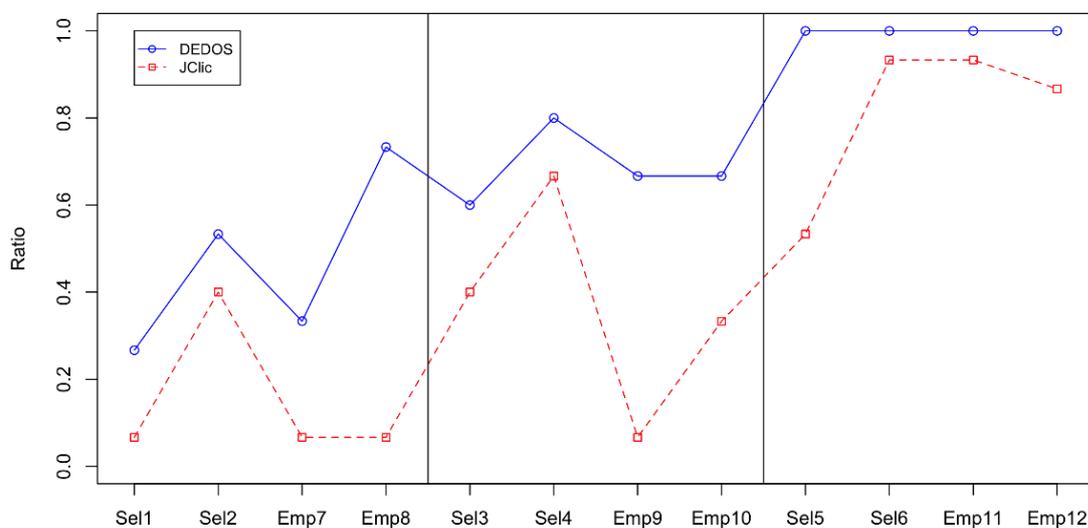
Figure 65. General evolution of the completion rate

Although the entry points are quite similar for both tools, the difference in their learning curves is nonetheless impressive. DEDOS-Editor shows a smoother learning curve with small fluctuations when changing the type of activities, while JClic-Author displays drops when changing activities. As we have seen in previous sections, these drops do not occur when analysing the learning curves of both types of activities

separately. Nevertheless, due to the characteristics of JClic-Author, the knowledge gained when designing multiple-choice activities cannot be used when designing pair-matching activities ('I do not even know where to start'[4]). Thus, when plotting both curves together (see Figure 65), there are drastic drops corresponding to the learning curve intersections. As a holistic tool, knowledge and experience in one type of activity help boost performance in any other type in DEDOS-Editor ('Designing pair-matching activities with DEDOS seems way easier than with JClic'). This smooths the learning curve as a whole, as shown in the upward trend throughout all sessions with DEDOS-Editor. We also believe that as the activities become more complicated to design (e.g. multiple-choice activities are easier to design than pair-matching activities), the difference in design paradigms becomes more noticeable.

We estimated the complexity of both tools according to Murray's variables (Murray, 2004) and discovered that the main problem of current authoring tools could be the vast number of elements and functionality offered, which increases the difficulty when trying to manage all of them. In DEDOS-Editor, there are few elements that can be dropped into the editing area to create the activities. Meanwhile, JClic-Author has a more complex structure in which elements have more parameters that must be learned in order to properly use the tool ('JClic has a lot of confusing options'). In contrast, our experiment showed that a little extra help allowed users to completely master DEDOS-Editor in the last session, reaching a 100% completion rate for all activities ('I have learned how to use DEDOS without asking anyone').

When analysing expert and novice users separately, we observed that not even expert users are capable of avoiding the drastic completion rate drops with JClic-Author (see Figure 66). Advanced users of DEDOS-Editor, on the other hand, were able to master the tool at the end of Session 1 and maintain a completion rate near 100% throughout the rest of the experimental study. In addition, users were able to reach completion rates similar to those of expert users with DEDOS-Editor at the beginning of Session 3, while they failed to do so with JClic-Author. Therefore, background knowledge was not a determining factor in the learning curve, as other authors have stated (Ainsworth & Grimshaw, 2004). If this were the case, the JClic-Author learning curve would be smoother than that of DEDOS-Editor since participants had previous knowledge of the tool. We believe that the complexity of the JClic-Author interface does not help the

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[4] Participant's comment

participants to retain the knowledge acquired from using the tool previously (Elliot et al., 2002), making it difficult to use the tool again after some time. However, further studies should be conducted with more participants since each of the groups (novices and experts) had different numbers of members, which made the expert group more sensitive to differences.
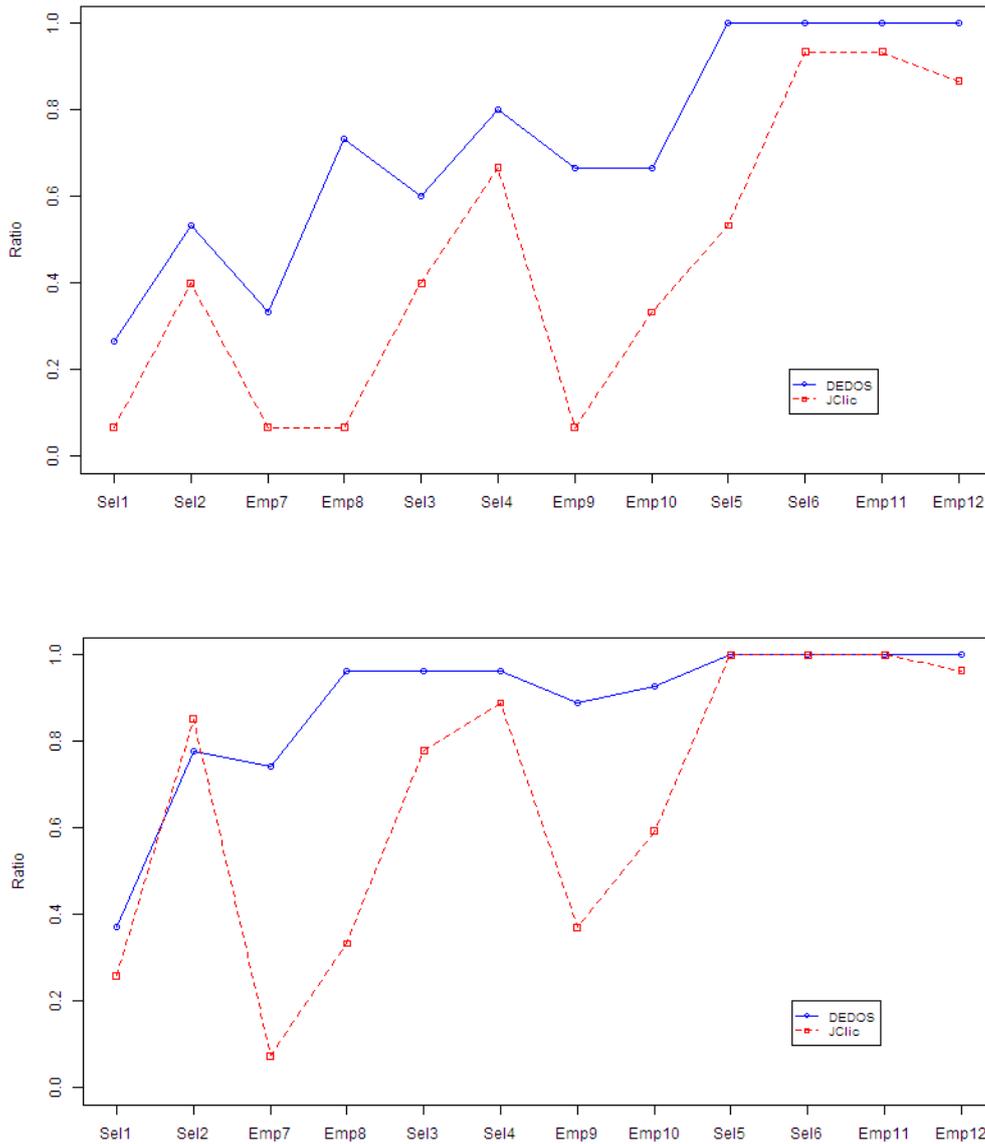
Figure 66. General evolution of the completion rate divided by groups

DEDOS-Editor's design, which favours intuition and continuous learning, is achieved through a direct manipulation paradigm and a strong core of common concepts that are maintained regardless of activity type. We believe that these features help

enhance the tool's generalisability. Despite not having the same amount of activities to design (only multiple-choice, pair-matching, addition and connect the dots activities), this paradigm choice has proven results in three significant outcomes which are closely related to those presented by van Oostendorp and Walbeehm (1995) regarding direct manipulation interfaces. First, and most importantly, the competence acquired in designing one type of activity improves the general results of creating any other activity type. Second, with some experience and information, novice users rapidly gain expert competence in the tool. Finally, expert users (meaning those who are more fluent in the use of technology in general, rather than having any prior experience with the tool) only need to experiment with the tool for a short period of time in order to master it fully, even with a complete lack of information.

JClic-Author's interface is based on menus and templates, and offers a guided creation process in which the interface changes (more or less subtly) with the user's choices to only offer options relevant to the current development. Intuitively, this type of interface may seem to be a very promising approach in which an apparently simple initial choice restricts options to those which are meaningful to that choice. However, the results suggest that the initial choice is not always as simple as intended by the interface developer, leading many users astray when dealing with an option for the first time. Second, and most important, is the fact that the clustered user interface where a tool has mini-tools for specific tasks drastically affects learning by clustering the learning process and majorly impeding reuse of knowledge in future tasks. To be fair, JClic-Author allows the user to design a great variety of activities, so it is difficult to use the same design metaphor for all of them. However, this does not impede the developer in using the same metaphor in activities that are similar to each other (such as multiple-choice and pair-matching). Besides resulting in a slower learning curve, this issue gives rise to a dangerously frustrating situation in which users with relative mastery of the tool for one particular task see themselves pushed back to square one when dealing with another slightly different task.

Our experimental study was conducted with young students, so we cannot conclude whether the results would be the same with actual teachers. Nevertheless, participants did not have any previous knowledge about DEDOS-Editor, and they gained expertise with this tool quickly throughout all the sessions. Thus, we could expect similar

results with actual teachers, whose knowledge about DEDOS-Editor would be at least as high as that of the participants in this study.

Our research shows how different designs which are aimed at solving the same tasks (multiple-choice activities and pair-matching activities) can produce a different user experience. The direct manipulation interface and the holistic, coherent creation paradigm seem to allow expert users to master the tool through limited experience, while allowing novice users to gain expert competence quickly with little information. Most importantly, the learning process is smoother and allows a higher entry point due to the intuitiveness of direct manipulation. In turn, the user can take full advantage of any prior experience with the tool in dealing with new situations, and thus avoid any frustrating drops in competence when facing new challenges. Although we need to perform more studies with different authoring tools, it seems that a direct manipulation interface and a coherent paradigm design help teachers to ease their workload, since they do not need to spend much time learning how to use the tool or creating the learning materials (Constantin et al., 2014). In addition, authoring tools with direct manipulation interfaces usually follow a 'what you see is what you get' metaphor (e.g. Smart Notebook), which makes it easier to provide situational awareness to users and lets them clearly see the consequences of their actions. This makes the application easier to explore (Vigo et al., 2014), and therefore enhances the tool's predictability.

Authoring tools should focus not only on functional aspects, but also on non-functional characteristics. Providing support to non-functional requirements is fundamental in order to allow users to complete their tasks (Lima et al., 2011). Most of the authoring tools reviewed in Chapter 2 seem to focus on functional aspects only, and fail to provide efficient support to users. With our experimental study, we have taken a first step towards clarifying which aspects could be relevant to teachers' adoption of a certain authoring tool, showing that direct manipulation interfaces could help provide the non-functional factors that appear to be disregarded when designing new learning tools. This factor was reflected in the satisfaction questionnaire, where participants valued the ease of learning of DEDOS-Editor over the extensive functionality provided by JClic-Author.

CHAPTER 7: CHILDHOOD EDUCATION

This chapter details three learning experiments that were carried out in childhood education (Quintanar, 2016; Guzmán, 2015; Fernández-Gaullés, 2014). These studies compare the use of new technological devices such as tablet computers and interactive whiteboards with the use of more traditional methodologies such as paper cards. Students who worked with the interactive whiteboard were more participative, and if one of the members did not know the answer, his/her peers would help. When using tablet computers, educational projects were solved individually. Both with technology and with paper cards, students had their teacher's support in order to read the questions and answers of the activities since students at this age are still acquiring literacy skills. The following sections describe each learning experiment, including the results and a joint discussion about the conclusions drawn from this education level.

7.1 Methodology

The three learning experiments presented in this chapter started between the last week of November and the first week of December, and ended between the last week of February and the first week of March. Therefore, the three studies had an approximate duration of three and a half months in which the participants completed between one and three sessions each week. All the studies were divided into three phases.

In the first phase, the participants completed a pre-test that measured their initial knowledge of several concepts within the framework of the decree 17/2008 of 6 March, of the Consejo de Gobierno de la Comunidad de Madrid para Educación Infantil. Once the participants had taken this test, they were divided into homogeneous groups composed of students with different knowledge levels. In the first two learning experiments, the 20 students were divided into two groups of 10, while in the third learning experiment the 24 students were divided into three groups of 8.

Once the participants had been grouped, each group was assigned a methodology to solve the proposed educational activities. In all the experiments, one group had to solve the activities using paper cards, while the other group(s) used technology. In the first learning experiment, the second group solved the activities using an interactive whiteboard. In the second learning experiment, the second group used tablet computers. Since there were three groups in the third learning experiment, the second group used tablet computers while the third used an interactive whiteboard. The assigning of the

methodology to each group was done by the pedagogical teams of the institutions; however, before starting the experiment, we checked whether each group had approximately the same knowledge level. In the final phase, participants had to complete a post-test which measured if there had been any evolution in their knowledge over the course of the experiment.

Regarding the concepts dealt with in the activities, the projects combined concepts covered prior to the experiment with new content that the students would have to learn throughout the duration of the experiments. This combination was chosen in order to reduce the level of frustration that could arise if participants failed many times, a scenario that could result if only new concepts were presented. In addition, this also helped to reduce the boredom that could occur if participants only had to solve activities about concepts they had worked on previously.

7.2 Measurement instruments

The three learning experiments aimed to measure the level of knowledge acquired by the participants, and whether technology positively impacted their learning process. To obtain data about knowledge gain, participants had to complete a pre-test and post-test on paper. Participants did not have a time limit, and the tests had to be solved individually. Both tests were composed of the same activities, which were similar to those the participants would solve during the learning experiment. The concepts established by the pedagogical team were included throughout the tests. The activities on those tests were different from the ones used during the experiment, so that participants could not memorise the answers. In the first experiment, the tests had 15 activities; in the second experiment, 24 activities; and in the third experiment, 12 activities. Figure 67 shows one of the participants taking the test.

In addition, we used direct observation to note the attitudes and interactions of the participants throughout the sessions, as well as any other aspects which could help in understanding the results. In each of the sessions of the three learning experiments, a minimum of two observers were in the classroom to take notes and to help the participants if needed.
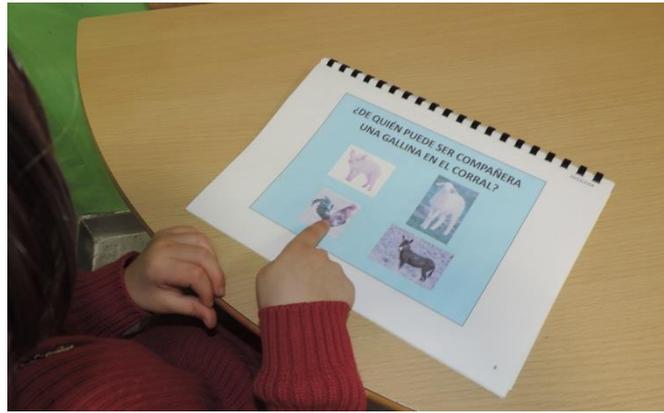
Figure 67. Childhood education, Example of a pre-test activity

7.3 First study: Interactive whiteboard vs. paper cards

The participants of this study were students from the institution C.P. María Moliner de Parla (Madrid). These students were 3 years old, and were chosen from two different classrooms. There were a total of 20 participants, including 10 students from each classroom. The selection was made according to students' academic level and skills; students with different profiles were chosen from within the same classroom so that we could obtain a representative sample. In this study, 10 participants used an interactive whiteboard. They were divided into two subgroups of 5 students each in order to facilitate the interaction with the device. Lastly, it should be mentioned that three participants with special needs participated in this experiment. Two were assigned to the paper group: one with an attention deficit disorder, and the other with developmental issues. The last student, who has language problems, was included in the interactive whiteboard group.

7.3.1 Educational project

Within the decree mentioned above, the activities were centred on 'Environment Knowledge' and 'Languages: Communication and Representation'. In the first type of activities, the participants worked with tall/short and fat/thin concepts. In total, 23 multiple-choice activities were designed, which could have one or multiple correct answers. Figure 68 shows an example of an activity about 'Environment Knowledge' in which the concepts of fat and thin are addressed, along with an example of an activity about 'Languages: Communication and Representation' in which the participants work on language.

Figure 68. First childhood education experiment, Activities

7.3.2 Evaluation

This section presents the results of the pre-test and post-test. These results will allow us to check whether significant learning took place over the course of this educational experiment. The main observations made in the classroom while the participants were solving the activities will also be discussed.

7.3.2.1 Quantitative analysis

One of the first questions we wanted to validate was whether the group formation was appropriate so that the knowledge level of the groups would be similar. Therefore, we analysed the number of activities solved correctly in the pre-test, which was composed of 15 questions. During the pre-test, teachers supported the students in order to avoid frustration caused by failing many times. An activity is considered finished correctly if the participant has given all the answers without making any wrong choices during the process and without needing any support. The outcome of this analysis can be found in Table 13. The results are similar, which verifies that the groups were created in a homogeneous way.

Table 13. First childhood education experiment, Pre-test results

	IW	Paper
Mean	6.2	6.6
Median	6	7
Standard deviation	3.94	2.91

The next step was to analyse the results of the post-test to measure whether significant learning took place. Figure 69 shows an initial comparison of the mean number of correct answers given on the post-test, comparing this with the results of the pre-test

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from both groups. It is possible to observe that the mean number of correct answers is higher in the group which used the interactive whiteboard (M=12), although these participants started at a lower knowledge level than the group which worked on paper (M=7.4).
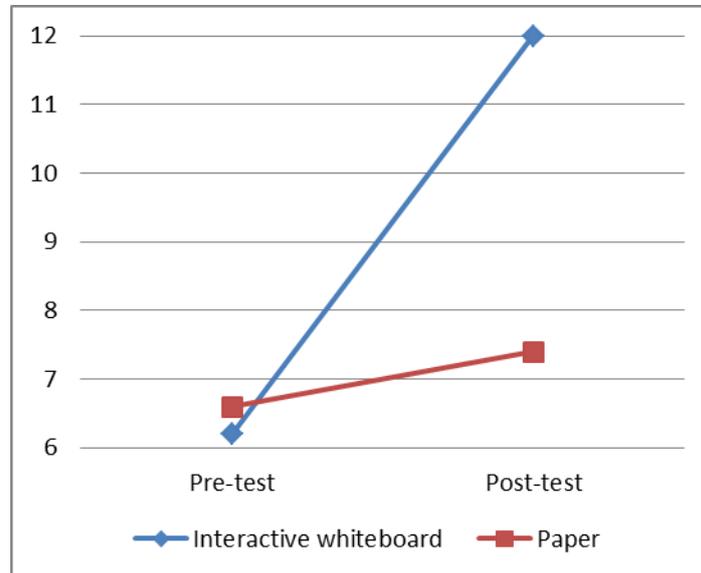
Figure 69. First childhood education experiment, Pre-test and post-test results

To verify whether these results are relevant, it is necessary to perform a statistical test to determine whether the hypothesis that the participants who interacted with the interactive whiteboard learned more than the participants who solved the activities on paper is true. Since none of the distributions are normal, it is necessary to apply the Wilcoxon signed-rank test. By applying this test, we observe that the students who used the interactive whiteboard increased their knowledge significantly (W=0, Z=-2.80, p<0.001, r=0.63). However, when applying the same test to the group that worked on paper, we cannot say that the improvement was significant (W=17, Z=-0.72, p=0.26).

Figure 70 contains a visual representation of the results of the students who performed the activities on paper. This graph reveals that there was no notable improvement. It should be highlighted that participants P14 and P15 were the students with special needs, and they did not demonstrate good performance.
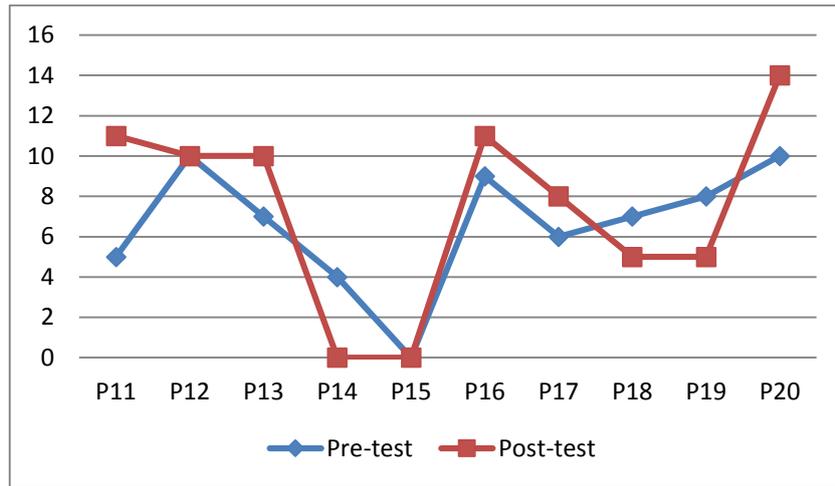
Figure 70. First childhood education experiment, Paper group results

On the other hand, Figure 71 shows the results of the participants who worked with the interactive whiteboard. This graph indicates that all the participants gave more correct answers on the post-test than on the pre-test. Moreover, in most cases the participants presented a notable evolution in the number of right answers. Therefore, taking into account the results of the Wilcoxon text, we can conclude that the participants who worked with the interactive whiteboard acquired more knowledge than those who worked with paper cards.
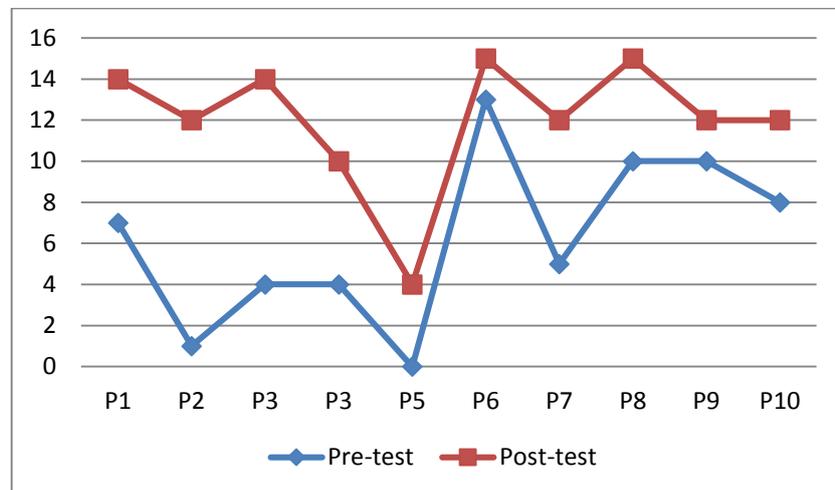
Figure 71. First childhood education experiment, Interactive whiteboard results

Now that the results of each participant have been analysed, the results of each activity will be presented. Figure 72 shows a normalised representation of the success percentage in each of the activities. The values range between 0 (no one answered correctly) and 1 (all the participants answered correctly). Again, this graph helps to demonstrate that the participants who worked with the interactive whiteboard obtained

better results in all of the activities. However, both groups present considerable decreases in some of the activities, which correspond to those activities which had more than one correct answer. In most cases, participants did not give all the correct answers; this happened in activities 9 and 11, which had three correct answers.
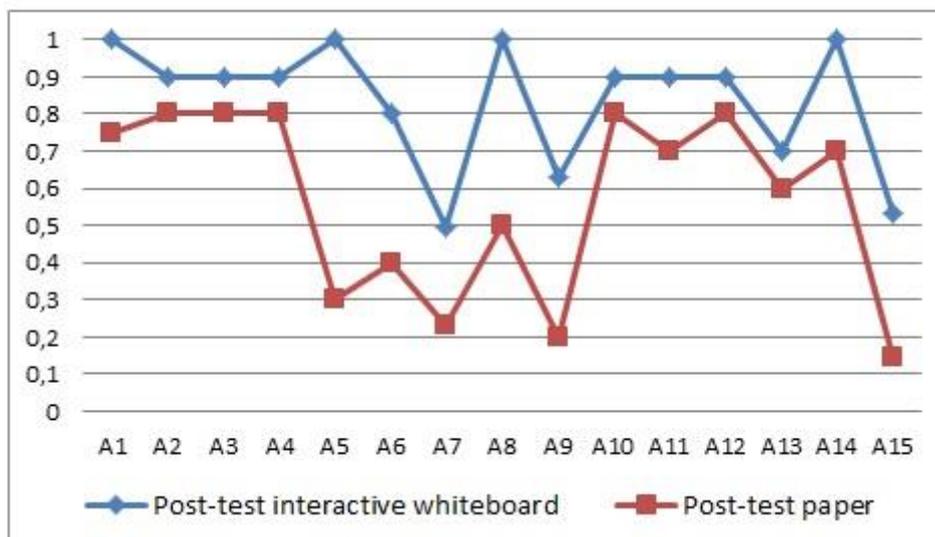
Figure 72. First childhood education experiment, Post-test results per activity

7.3.2.2 Direct observation

Apart from the results obtained in the tests, the motivation of the participants varied depending on the device they used: interactive whiteboards versus paper cards. Students who worked with the interactive whiteboard were more motivated when solving the activities, and helped their peers more. Even the student with language issues (P5), who did not understand everything, was enthusiastic when working this way. However, the participants who worked with paper cards were not particularly motivated in this experiment, and in many occasions became distracted. This behaviour pattern was repeated throughout the different sessions of the experiment.

7.4 Second study: Tablet computers vs. paper cards

This section presents a study in which main goal was to evaluate whether there was a positive influence when using technology, in particular tablet computers, on students' learning in Childhood Education (Roldán-Álvarez et al., 2016). Participants were students from the school Valle del Miró of Valdemoro in Madrid. In total, there were 20 students aged 5 years old, divided into two groups of 10 students each. The first group solved the activities with tablet computers, while the second group worked with

paper cards. The grouping was arranged by the pedagogical team of the centre, so each group had a similar knowledge level in order to properly evaluate the knowledge gain.

7.4.1 Educational project

The activities of this study were based on the second block 'Approach to Nature' of area 2 of 'Environment knowledge' of the decree mentioned in Section 7.1. In addition, students also worked math activities contained in the first block of 'Physical Media: elements, relations and measure'.

The activities were grouped into three educational projects, each covering a different topic within the block mentioned in the previous paragraph (domestic animals, farm animals and wild animals). In these activities, the students worked on animal identification as well as other concepts such as their habitat and diet (see Figure 73). In each of the educational projects, there were three different types of activities: multiple-choice, pair-matching and addition.
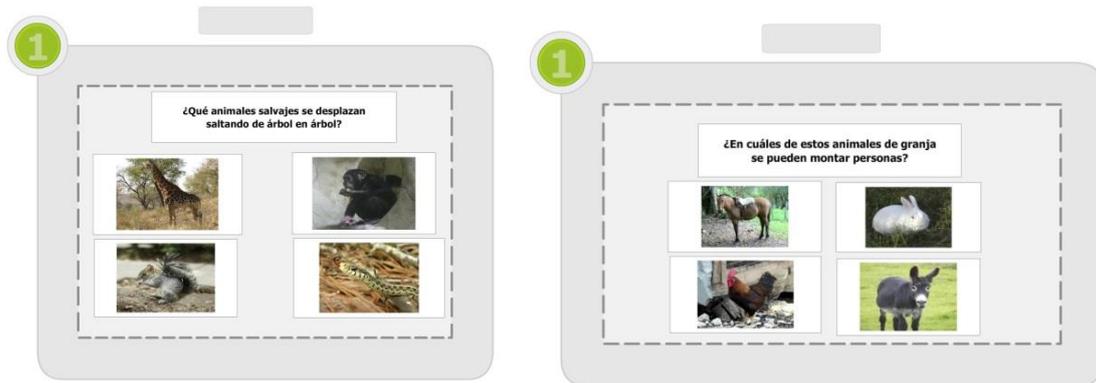
Figure 73. Second childhood education experiment, Multiple-choice activity about wild animals and multiple-choice activity about farm animals

Figure 74 shows an example of an addition activity about domestic animals. In this activity, participants had to give the owner his/her seven dogs. Any combination of dogs which added up to seven would be valid, so there was more than one correct answer to this activity.
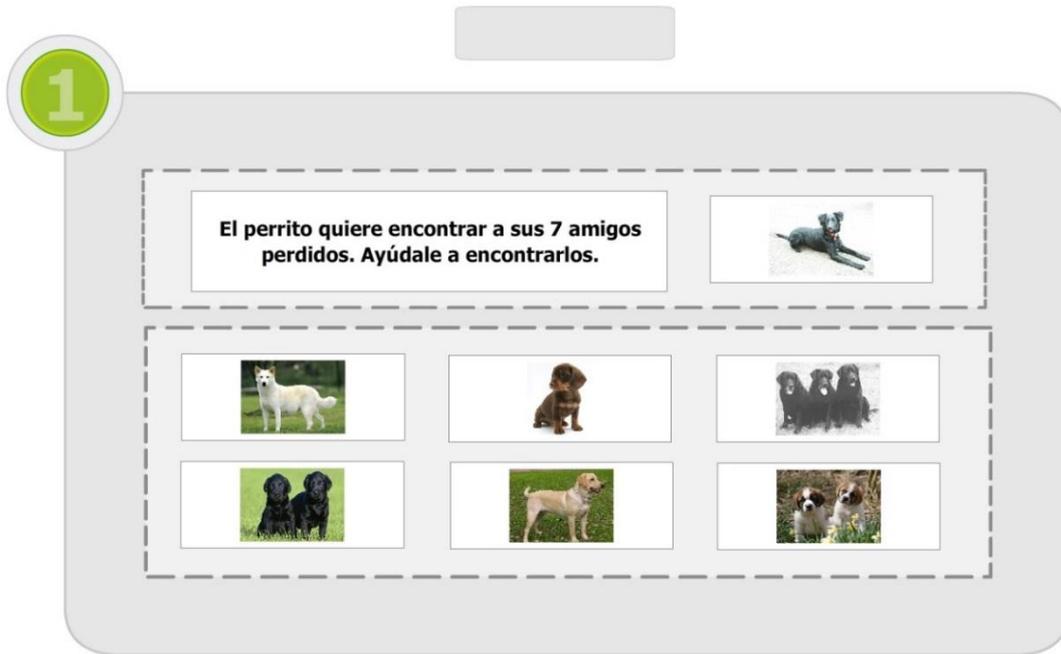
Figure 74. Second childhood education experiment, Addition activity

7.4.2 Evaluation

This section describes the results obtained from the tests, along with the main conclusions drawn by the observers during the learning experiment.

7.4.2.1 Quantitative analysis

As in the previous experiment, in order to evaluate whether the groups were formed with similar knowledge levels, the results of the pre-test were analysed. The results are similar for both groups (see Table 14), although it could be said that the group that worked with paper cards had a superior knowledge level. This test was composed of 24 activities, each of which was valued at one point; thus, each participant could score a maximum of 24 points.

Table 14. Second childhood education experiment, Pre-test results

	Tablets	**Paper**
Mean	14.53	15.97
Median	14.18	17.21
Std. Deviation	2.56	3.13

We then proceeded to analyse learning. Due to the small size of the sample (N=10), we used the Wilcoxon signed-rank test. When applying this test, we assumed that the number of mistakes the participants made on the post-test should be lower than on the pre-test, since the concepts covered on the post-test were worked on during the study. On the one hand, the difference between the pre-test and post-test results obtained by the group which used tablet computers was large and significant (W=0, Z=2.8, p<0.001, r=0.62). On the other hand, as in the previous learning experiment, the group which worked with paper cards did not experience an improvement between the pre-test and the post-test, although this result was not statistically significant (W=41, Z=1.38, p=0.19). Figure 75 shows an evolution of the mean scores on the pre-test and post-test.
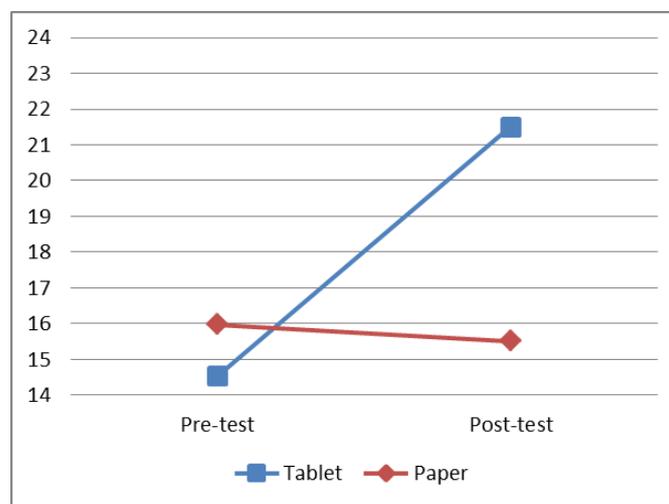
Figure 75. Second childhood education experiment, Mean of correct answers on the pre-test and post-test

The difference between the evolution of both groups is more visible if we represent the results of the pre-test and post-test while taking into account the number of activities completed by each student. Figure 76 shows the test results of the participants who solved the activities on paper. It is evident that there is no clear positive evolution for most of the participants. However, when viewing the results of the group which worked with tablet computers (see Figure 77), an improvement can be seen in the number of activities solved correctly. Therefore, the previous statistical analysis combined with the visual representation of each student's results show that the group which worked with tablet computers displayed better learning than the group which used paper cards.
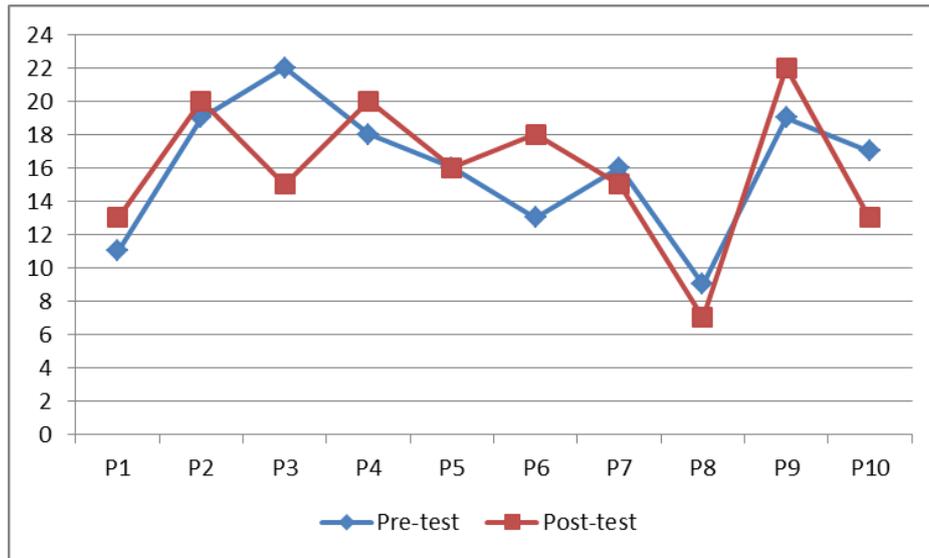
Figure 76. Second childhood education experiment, Pre-test and post-test results per participant, Paper methodology
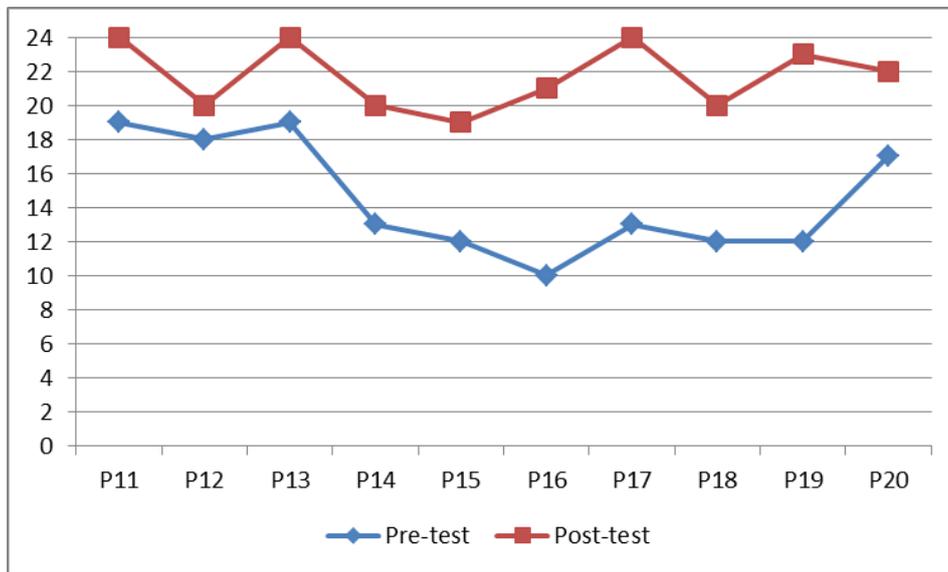
Figure 77. Second childhood education experiment, Pre-test and post-test results, Tablet computers methodology

Lastly, Figure 78 presents the post-test results of both groups, normalised by activity. In each activity, participants could obtain a score from 0 (he/she has not completed any goal) to 1 (the student has completed all the goals). Since some activities could have more than one goal, for instance four correct answers, it is possible to find values between these two scores; for example, if the student chose two out of four goals correctly, he/she would receive a score of 0.5. It can be seen that the results of the students who used tablet computers were higher than the results of the students who solved the activities on paper.

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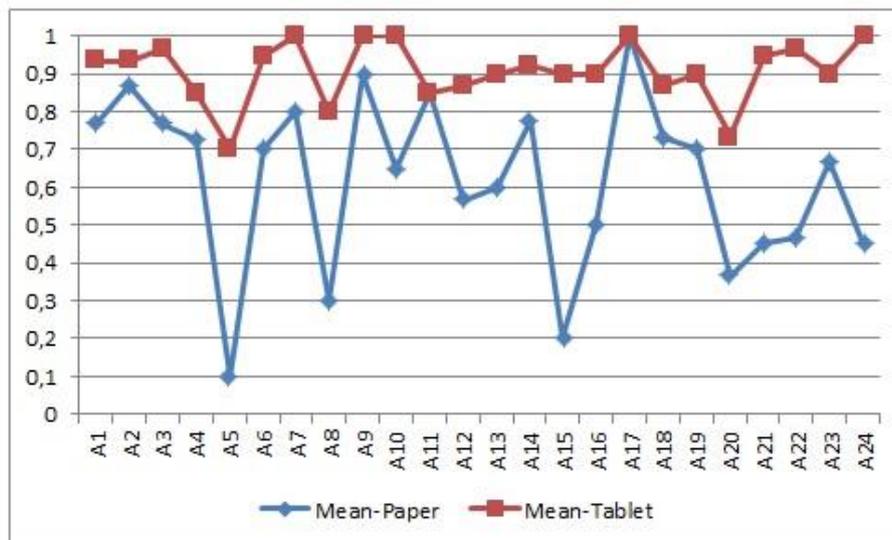
Figure 78. Second childhood education experiment, Post-test results normalised per activity

Both groups show decreases in several activities, which correspond to those activities with more than one goal. In this type of activity, students usually did not give all the answers, so they never completed the activity correctly. The largest differences are found in activities A5, A8, A15, A21, A22 and A24, for which there is a difference of between 0.5 and 0.7 points between both groups. These differences are attributed to the following causes.

A5 and A8 consisted of identifying which farm animal lives in a barn or in a pen, concepts that were unknown to the participants in the pre-test. Those who used tablet computers received feedback from the application if they failed, which helped them to remember these concepts.

- In activity A15, participants had to identify which animal can carry people. In this case, students did not know what 'transport' meant, which resulted in many mistakes.

- In A21 and A24, participants had to identify which wild animals were herbivorous or omnivorous. Since they did not understand this concept very well, many students gave wrong answers.

- A22 consisted of identifying which farm animals can give milk (cow, goat and sheep). Many participants chose the cow, but did not select both the cow and the goat, so they did not complete the activity correctly.

7.4.2.2 Direct observation

Throughout the entire study, a palpable difference was noted in the motivation of both groups. While the participants who used tablet computers showed great interest, the students who worked on paper were not as motivated; this is a factor that may justify the results obtained by that group. On many occasions, the participants of the paper group asked about the tablet computer ('When will I play with the tablet?'[5]). This led the teachers to motivate the students so that their performance would not be affected, allowing them to use the tablet computer once the session had ended. On the other hand, participants of the group that used the tablet computers saw the activities as a game. This caused them to be motivated since they viewed the activities as something fun to do, and not as classwork.

It is important to mention that the change of methodology when completing the activities could have played an important role. In the case of the paper group, participants did the activities in the same way they had always done in their classroom, which resulted in boredom and loss of interest. On the other hand, the change of methodology experienced by the students who used tablet computers increased their motivation; they saw that apart from doing the same activities as their peers, they could also play with the tablet computer. This situation leads us to believe that the combination of traditional methodologies with technology can help prevent students from becoming bored, and can keep them motivated throughout the process of doing educational activities in the classroom.

7.5 Third study: Tablet computers vs. interactive whiteboard vs. paper cards

After the previous two studies, we carried out another study in which the three methodologies used before were combined. In this learning experiment, students from the school San Miguel Arcángel of Madrid participated. In this case, students were 5 years old. In total, there were 24 students who were divided into three groups. Each group solved the activities in a different way: interactive whiteboard, tablet computers or paper cards.

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[5] Participant's comment

7.5.1 Educational project

The educational project was made up of 24 activities. Among these were multiple-choice activities, pair-matching activities and addition activities. The activities in this experiment focused on the second area of 'Environment Knowledge', and were based on the Olympic Games (see an example in Figure 79). Parallel to this topic, participants also worked on mathematical-logic concepts such as addition and sets of elements (see an example in Figure 80). Lastly, some activities about emotion recognition were included as well (see activities in Figure 81).

Figure 79. Third childhood education experiment, Multiple-choice activity

Figure 80. Third childhood education experiment, Pair-matching activity

Figure 81. Third childhood education experiment, Emotion recognition activity

7.5.2 Evaluation

In this experiment we carried out the same analysis as in the previous experiment: checking whether the groups formed were homogeneous, evaluating the results of the pre-test and post-test, and drawing conclusions through direct observation.

7.5.2.1 Quantitative analysis

The pre-test of this study was composed of 12 activities. As in the previous experiments, we verified whether the group composition was homogeneous. Table 15 presents minimal differences among the three groups. Therefore, all groups started the experiment with similar prior knowledge. It should be pointed that in the tablet computer group, there was a student with little knowledge who did not finish the experiment due to encountering significant problems when trying to understand the activities.

Table 15. Third childhood education experiment, Preliminary analysis of the pre-test results

	Paper	IW	Tablet
Mean	7.75	8.38	8.71
Median	9	8	9
S. deviation	2.44	1.51	1.98

Having confirmed that all the groups started from the same knowledge level, it is now necessary to check whether there was a positive evolution in students' knowledge throughout the study. The results of the pre-test and post-test are shown in Figure 82. The greatest difference between the pre-test and post-test can be seen in the group that worked with the interactive whiteboard, while the group that performed the activities on tablet

computers presented the lowest difference. However, this low variation is due to the fact that this group started from a slightly higher knowledge level than the other groups, and thus had a lower growth margin. Moreover, the group that performed the activities on paper had the worst results among the three groups.
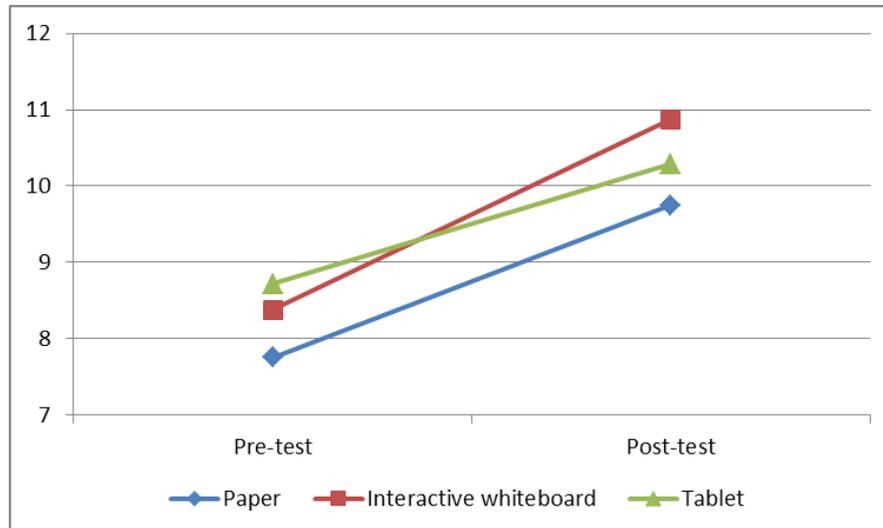
Figure 82. Third childhood education experiment, General results of the pre-test and post-test (mean)

As the general data have been presented, we may proceed to examine the specific results of each group. Figure 83 shows the pre-test and post-test results of the group that performed the activities on paper. In general, the participants of this group achieved better results on the post-test than on the pre-test, although two participants did not improve. Only one of the participants answered all the activities on the post-test correctly.

Next, Figure 84 presents the results of the group which solved the activities using tablet computers. In this case, apart from participant P10, who solved all the activities in the pre-test and post-test correctly, all the participants improved by at least one point on the post-test. P15 can be highlighted in this group, since this participant answered four more activities correctly on the post-test than on the pre-test.
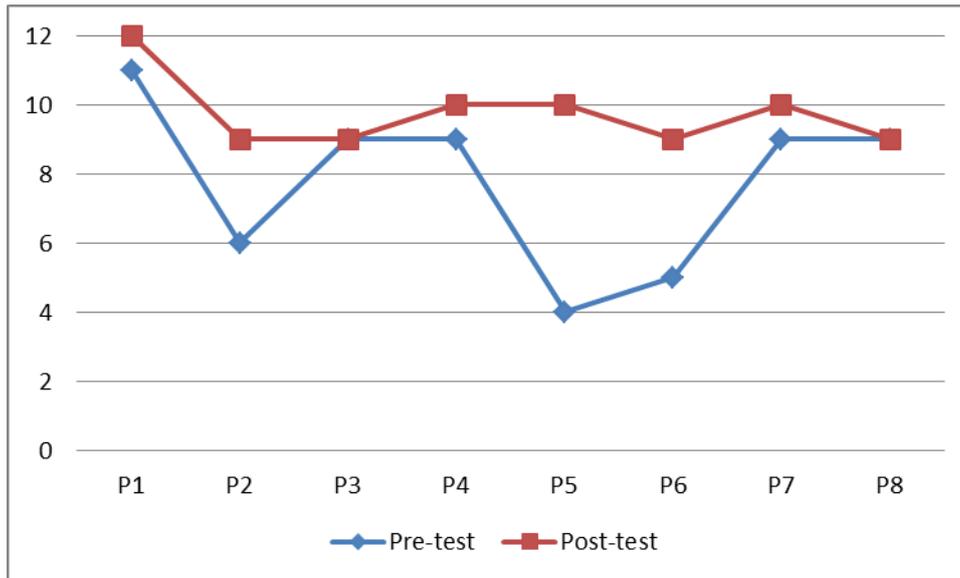
Figure 83. Third childhood education learning experiment, Paper group results
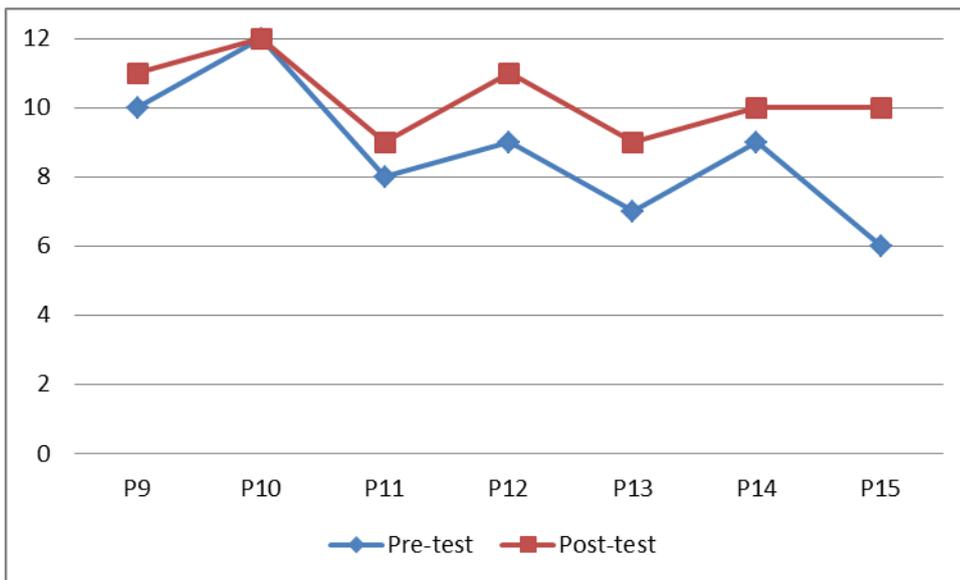
Figure 84. Third childhood education experiment, Results of the tablet computer group

Lastly, Figure 85 presents the results of the group which solved the activities on an interactive whiteboard. In this group, it is clear that all the participants obtained better results on the post-test than on the pre-test. P23 solved all the activities correctly, and P16, P17, P19 and P20 answered at least three more activities correctly on the post-test.

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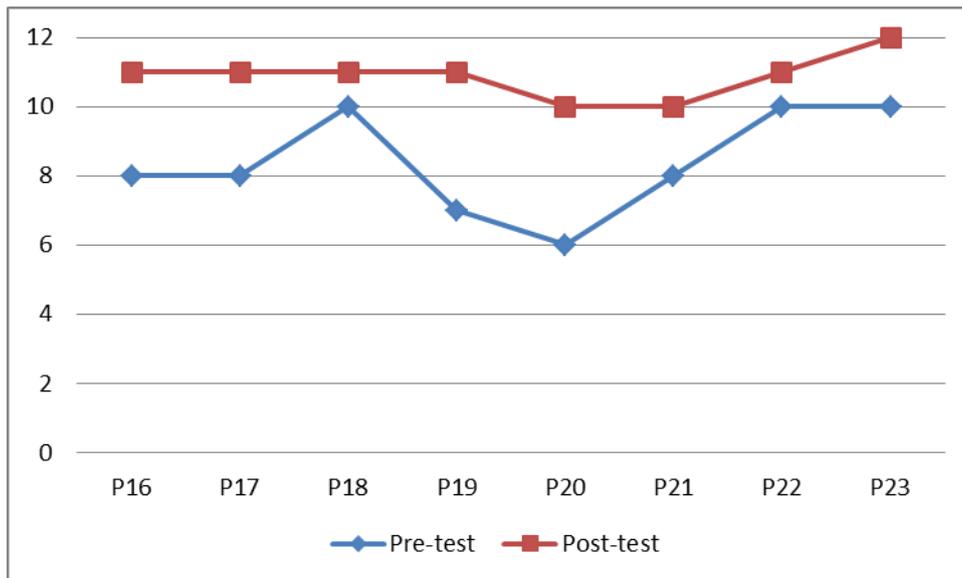
Figure 85. Third childhood education experiment, Interactive whiteboard group

The results per activity are shown in Figure 86. In this graph, the results are presented in a normalised manner. Each activity can have a score from 0 (no one solved any goals of the activity) to 1 (all the participants solved all the goals of the activity). As can be seen, there is not much difference among the three groups. However, as shown in the previous studies, we can observe decreases in those activities with more than one goal.
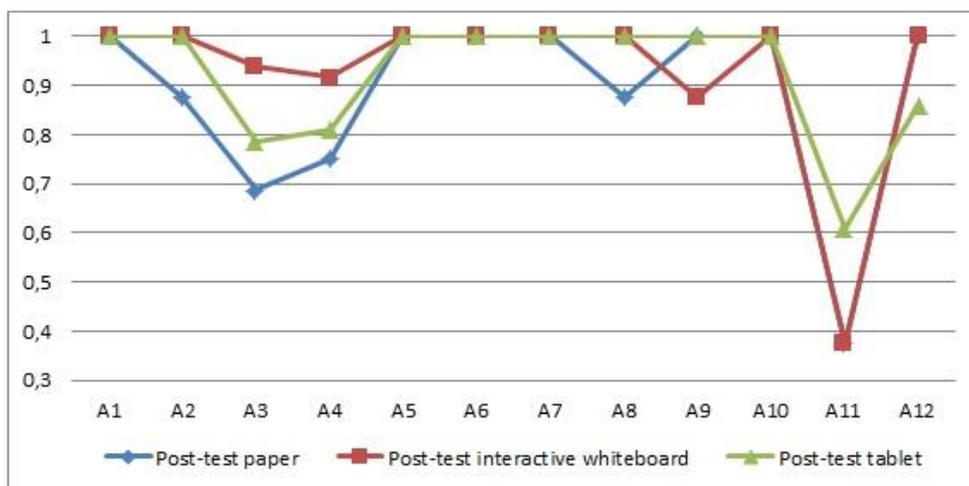
Figure 86. Third childhood education experiment, Post-test results per activity

Reviewing these results, we cannot observe substantial differences among the three groups. Therefore, we decided to use the Kruskal-Wallis test, a non-parametric test. Although this test has less precision than parametric tests, it is the most frequently used when the sample size is too small. This is the most appropriate test for this study, since

each group had eight participants. After applying the test to the samples, we determined a result of p = 0.096. This means that there is no significant difference, so it does not allow us to affirm that the best methodology is the use of interactive whiteboards in the classroom.

Moreover, we carried out two additional tests: HSD Tukey and Games-Howell. In these tests, we compared the results by pairs: paper and interactive whiteboard, interactive whiteboard and tablet computer, and paper and tablet computer. However, these tests revealed no significant differences, so no conclusions can be drawn with respect to which methodology was better for students' learning.

7.5.2.3 Direct observation

Regarding group motivation depending on the methodology used, the group with the highest motivation when solving the educational activities was the one which used the interactive whiteboard. In this group, participant P20, who had attention deficit disorder, performed well when doing the activities. This participant showed happiness each time he/she solved an activity correctly. One factor to highlight was the cohesion and good working environment of this group. Participants in the interactive whiteboard group were happy to be required to solve the activities. In addition, if any of these students had trouble trying to find the answer, they did not hesitate to ask for help from their peers, who also helped anyone who had problems when trying to understand what to do. It seems that the use of the interactive whiteboard caused students who were not usually motivated, such as P19 and P21, to integrate in the group without problems and work on the activities in a more active and participative way.

Concerning the group which solved the activities on tablet computers, it first must said that the activities were solved individually. The participants of this group were also motivated when doing the activities, although there was a considerable difference between those who knew how to interact with the device and those who did not. This suggests that in order to do the activities on a tablet computer, it is necessary to explain how to interact with it. Tablet computers allow activities to be completed in a different way; this enabled participants such as P13, which had socialisation and attention problems, to show a degree of motivation that teachers had not seen before. Since the activities were done individually, the assessment could be carried out in a personalised manner.

Finally, the group which worked on paper did not show additional motivation, mostly because the way of solving the activities was the same as in their daily classes. In order to address this issue, teachers allowed the students to use other types of resources to solve the activities, such as markers, fluorescent highlighters and stickers. However, since the students sat in the same place and the teacher read the activities, students such as P2, P5 and P6, who do not usually show optimal performance, participated more when doing the activities. Working in this way created a reflection environment where all the participants commented on the answers and corrected themselves.

7.6 Discussion

The literature shows that one of the main factors to consider when integrating technology in the classroom is the teaching philosophy of teachers (Buxton et al., 1985). Nowadays, teachers are aware that the inclusion of technology in the classroom can enhance learning and make that learning a more inclusive and motivating task. However, teachers' lack of training in ICT (European Union, 2013) and the difficulties they face when choosing the appropriate application among the thousands on the market cause teachers to spend a great deal of time on tasks that are unrelated to teaching. In this context, providing a tool that allows digital content to be created for various learning scenarios and devices seems to be a key element of integrating technology in education.

Although the use of technology itself has unique properties, and while it is believed that the use of ICT can enhance students' learning, there is not enough knowledge regarding how the use of touch technologies and their interaction affects childhood students (Mueller et al., 2008). Added to this factor are the issues that arise when trying to find appropriate content for these kinds of devices. Moreover, difficulties emerge when trying to evaluate what students have learned and attempting to monitor their progress when doing educational activities.

Our studies have aimed to shed more light on this topic. The design and accessibility of touch interfaces allowed students to quickly learn how to interact with tablet computers and interactive whiteboards. As a result, teachers who were observing the students had to intervene only a few times, with most of the support being given in the first session of each experiment. In the subsequent sessions, students knew how to use the application autonomously.

In the studies carried out, students were able to move with the tablet computers and comment on the results with their peers. This meant they could discuss activities with a degree of freedom superior to that which they would have if they were using paper cards or a personal computer; this is a key factor highlighted in the literature (Beschorner & Hutchinson, 2013). In this regard, students who used technology were more motivated than those who performed the activities on paper.

On the other hand, the use of interactive whiteboards in particular is growing in classrooms. One of the features highlighted most often by students and teachers is the visibility of the content these whiteboards can offer, which allows students to be aware of what is happening. Tablet computers and personal computers do not allow this kind of interaction, since multiple students must gather around a small screen, or be divided into groups so that they can take turns interacting. This takes up more time for teachers, and does not solve the visibility issue.

Currently, there is a great deal of debate about what has made interactive whiteboards so popular. Some point out the ability to present the content with vibrant colours, along with the possibility to move and manipulate the content, all of which improves the learning process (Damcott et al., 2002). Others claim that this popularity is due to interactive whiteboards' ability to present a great variety of information, in the process making content more tangible and easier for students to grasp (Levy, 2002). Lastly, interactive whiteboards' ability to support different learning approaches has also been highlighted, since teachers have access to a wide range of resources to satisfy their students' needs (Glover et al., 2001). Our learning experiments replicate both findings, since teachers captured their students' attention with interactive whiteboards; this made them more eager to participate, which led to better learning than when using paper cards. Moreover, these surfaces facilitated the creation of participative working environments in which the group members helped their peers when they did not know the answer to an activity.

The interactivity of these surfaces has also been one of the most frequently highlighted features among students and teachers. However, this capability can only be used to its fullest potential if the appropriate software is implemented. In this regard, some teachers have commented that they usually use interactive whiteboards as a replacement for normal blackboards. This perspective may suggest that touch surfaces themselves do

not allow predicting the effects that their use can have on students' learning but software also has a big part in it.

It should be pointed out that, regarding the use of these devices, teachers were thankful for the knowledge they gained in order to be able to use technology for educational purposes. Several teachers who participated in our studies said that they were not able to use ICT in their classrooms since they did not have enough digital competences. Our studies led them to consider integrating technology in their classrooms to attract students' attention, especially those who do not usually participate in the activities proposed by the teacher. However, some researchers have advised that tablet computers, interactive whiteboards and multi-touch tabletops will initially attract students' attention because these devices are new. Consequently, this attention can dissipate once students become accustomed to the technology (Glover et al., 2007).

If we focus on the quantitative results after the statistical analysis, it can be confirmed that every childhood student obtained better results when using any of the technology devices mentioned in the previous sections compared to those who used paper cards. However, in the last experiment this difference was not significant, and all the students experienced similar knowledge growth. Due to the lack of motivation of the paper group in the first two experiment, we decided to include motivating elements such as markers and stickers so that the students would perform better. Although there were no significant differences, the motivation perceived by the educators was higher in the group which used interactive whiteboards, followed by tablet computers and, finally, paper cards.

One possible explanation for the differences in learning between the groups that used technology and those that did not is the level of motivation. In the literature, research has demonstrated the role of technology in increasing students' motivation during the learning process (Karsenti et al., 2016). Participants who used tablet computers and interactive whiteboards were always more motivated than the students who solved the activities on paper. For instance, when a participant was solving an activity on the interactive whiteboard, his/her peers helped him/her and everyone in the group discussed the answers. In the case of tablet computers, even if the activities were done individually, the students discussed the answers in groups; this replicates situations that have been described elsewhere in the literature with regard to using tablet computers (Dunn et al., 2016). In the second learning experiment, students who worked on paper constantly

showed their interest in using the tablet computer ('When can I play with the tablet?'). On the other hand, participants who were using the tablet computer concentrated on the activities as if they were a game. This game feeling was also replicated in the groups which used interactive whiteboards in the experiments. However, the groups which used paper often showed disinterest in the activities; this situation was especially notable in the first learning experiment described in this chapter.

Regarding interactive whiteboards, these were used as collaborative devices to solve activities in a group. In this environment, the interactive whiteboard was used by a group of students who interacted with the device at the same time to solve activities while they discussed and helped each other within the group. It seems that interactive whiteboards are appropriate for students to use simultaneously, which leads to an active exchange of ideas and opinions. For instance, students discussed the answers to the activities and voluntarily helped their peers if they did not know the answer to an activity. This is due to all the members of the group being aware of their peers' actions on the device, and this factor encouraged them to participate and express their opinions. In this regard, the positive factors about interactive whiteboards that have been highlighted in the literature could be seen in the group of students who used this device (Luo et al., 2016): interactivity, which enhances active learning; a large screen that facilitates working in groups; and accessibility for young students who have not yet acquired fine motor skills.

Although the participants who used tablet computers and paper worked at the same time, the individuality of tablets and the lack of motivation when working with paper impeded the same type of collaboration that occurred when students used an interactive whiteboard. Students who worked on paper did not care about what their peers were doing; similarly, although the students in the groups using tablet computers usually discussed the answers, it was impossible for each student to know what their peers did. However, some families reported that their children repeated some of the activities at home with their own tablets, which suggests that this kind of device could enable learning anytime and anywhere, thus creating a connection between institutions and homes (Blackwell, 2013).

In our learning experiments, the students quickly adapted to the use of touch devices. In less than 10 minutes they were able to perform the basic gestures to interact with the application, and in 20 minutes they had learned to interact without any help.

However, the use of interactive whiteboards posed some issues for the youngest students. For instance, the height at which this device is installed could impede students from interacting with the elements of the application, since some students may not be tall enough to reach them. In our experiments, this problem was notable in pair-matching activities since students had to move one card into another they could not reach. In this situation, some students leaned against the interactive whiteboard, but since the device only had one touch point it did not detect the real interaction the student wanted to perform. Contrary to what we expected, students were still motivated and, thanks to the teacher's help, they were able to resolve this issue. In this regard, it is necessary to take this factor into account in order to design accessible activities for every student and to install the interactive whiteboard at an appropriate height.

CHAPTER 8: PRIMARY EDUCATION

This section describes two educational experiments carried out in primary education (Rodriguez, 2013). In these experiments, we have designed activities with DEDOS-Editor focused on two of the main subject areas of primary education: Mathematics and Spanish Language and Literature. Similar to the childhood education experiments in the previous chapters, we worked with two groups of students who used either an interactive whiteboard or paper, in order to measure whether the use of technology has a positive impact on the learning process.

8.1 Participants

The participants of both experiments were 48 students from the sixth year of primary education at the public school Antonio Hernández, located in Móstoles (Madrid). These students were divided into two groups: 6ºA and 6ºB. The groups had similar skills and knowledge, and were created by the institution at the start of the school year.

8.2 Educational project

The activities designed for this study were based on article 17 of the Ley Orgánica de Educación, and the article of Real Decreto 1513/2006 of 7 December, which establishes the minimum educational requirements of primary education. Two educational projects were created, including one for each area. There were a total of 12 activities about Mathematics and 7 activities about Spanish Language and Literature. Within the area of mathematics, the students worked with polygons. For Spanish Language and Literature, students worked with suffixes, accents and pronouns. The activities were designed with DEDOS-Editor, and both topics included multiple-choice, pair-matching and addition activities.

Figure 87 shows an example of a multiple-choice activity about polygons, within the area of Mathematics. In this activity, participants had to select which of the proposed images was the correct one according to the question. On the other hand, Figure 88 shows an example of a Spanish Language and Literature activity. In this case, it is a pair-matching activity in which participants work on demonstrative pronouns. In the activity, participants have to match each image to the corresponding pronoun.
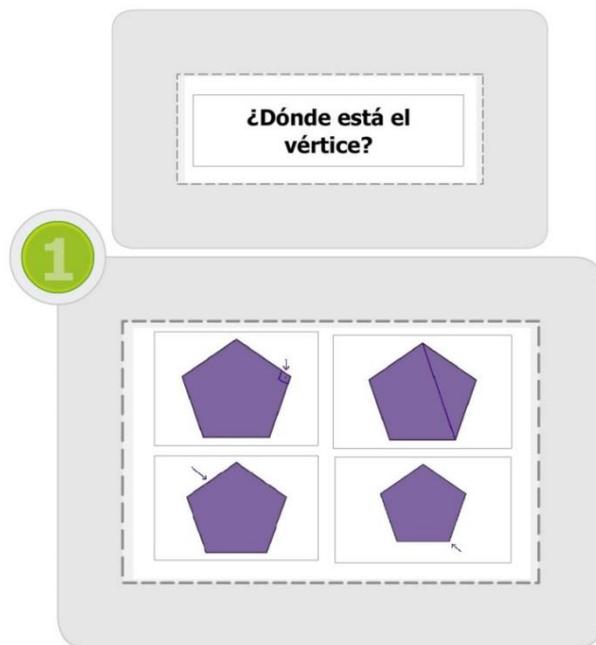
Figure 87. Primary education experiment, Polygon activity
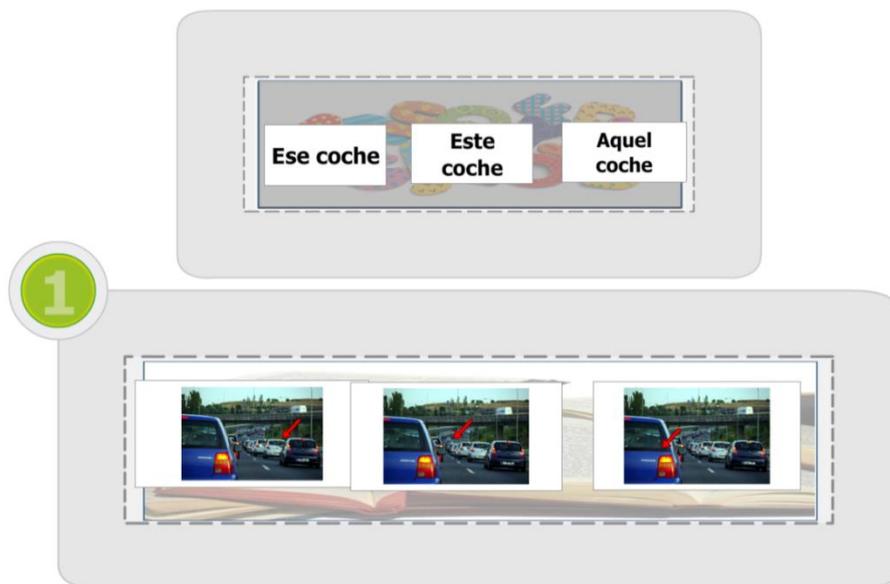
Figure 88. Primary education experiment, Demonstrative pronouns activity

8.3 Methodology

Firstly, participants were divided into two groups. The first group had to perform the activities with DEDOS-Player on an interactive whiteboard, and the second group worked with the activities on paper and on a blackboard. Both groups had the same amount of time to solve the activities; this was divided over four sessions of one hour each, as established by the pedagogical team of the institution.

So that every student in the experiment would have the opportunity to use the interactive whiteboard, we made sure that they worked on two different topics in order to change roles once one of the topics was completed. Accordingly, students in 6ºB worked on Spanish Language and Literature with the interactive whiteboard and performed Mathematics activities on paper and the blackboard, while the students in 6ºA worked on the Spanish Language and Literature activities using paper and the blackboard and Mathematics activities with the interactive whiteboard.

As with the childhood education experiments, the students had to complete a pre-test before starting the study in order to measure their previous knowledge. This pre-test was conducted during one class hour. Once their initial knowledge level was known, the participants started doing the activities using the corresponding methodology.

When the students used the interactive whiteboard, the teacher explained the topic using a textbook and a blackboard, and complemented the explanation by demonstrating activities on the interactive whiteboard. The activities were done by the teacher, who was guided by the students, or by the students guided by their partners. The group which solved the activities on paper did the activities in the book, and some activities were proposed in order to be completed in the notebook.

8.4 Measurement instruments

In this study we aimed to measure whether the use of technology influenced the learning process of the participants, so that they might gain more knowledge throughout the experiment. In order to do this, and as in the previous experiments, the users had to take a pre-test before the study with the goal of measuring their previous knowledge about the topics they would work with. At the end of the experiment, they also had to complete a post-test to measure their knowledge gain. Both trials were composed of the same activities, which allowed us to measure the evolution of each participant. In total, the tests included 12 activities: six related to Mathematics and six related to Spanish Language and Literature.

All the content covered in both tests was the same content the participants worked on during the experiment, although the format varied slightly. This way, although the concepts were the same, we prevented the students from memorising the answers.

8.5 Evaluation

In this section we describe the results obtained for this educational level. In this case, and in contrast to the previous experiments, both groups used both methodologies to do educational activities: one for the area of Mathematics, and another for Spanish Language and Literature. In order to evaluate the results, we divided these two topics and evaluated them separately.

8.5.1 Mathematics

Analysing the Mathematics results reveals that 47 participants obtained better scores on the post-test than on the pre-test, while only one student obtained a worse score. If we extract a summary of this data, we can observe that the mean of the pre-test is 13.49 points, while the mean of the post-test is 21.16 points. The maximum score was 31 points, which corresponds to the total goals of the activities which composed the tests. Figure 89 shows a summary of these tests results.
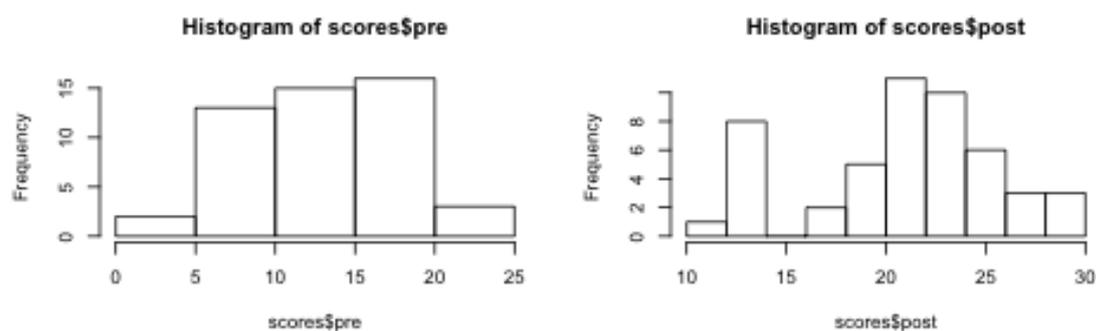
Figure 89. Primary education experiment, General results of the pre-test and post-test

The next step was to check whether both groups experienced significant learning. To do this, we first applied the Shapiro-Wilk test to evaluate the normality of the samples. Applying this test to the pre-test results yields $p=0.6595$, so this sample is normal. When applying this test to the post-test, we see that $p=0.02$. Since this value is lower than 0.05, we cannot assume that this second sample is normal; as a result, we cannot apply the Student's t-test. In its place, we used the Kolmogorov-Smirnov test to compare the samples, determining that $p<0.001$. Thus, the general learning growth of all the students was significant.

Next, we analysed the results by separating the groups according to the methodology used. By analysing these results, we observe that the 26 students who used the interactive whiteboard obtained better scores on the post-test, while in the group of

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22 students who used traditional methodologies, only one did not improve. It should be noted that, as it can be observed in Table 16, the participants of this second group had higher initial knowledge than the group which used an interactive whiteboard. Because of this, although the results of the post-test are similar for both groups, the first group showed a greater evolution.

Table 16. Primary education experiment, Summary of pre-test and post-test results according to methodology

		Interactive whiteboard	Traditional
Pre-test	Mean	11.69	15.52
	Median	11.50	16.00
	S. Deviation	04.13	04.01
Post-test	Mean	21.23	21.09
	Median	21.50	21.50
	S. Deviation	04.34	05.18

As in the previous test, we will now apply the same tests to the samples divided by methodology. This time we observe that when applying the Shapiro-Wilk test, all the samples are normal, so it is possible to apply the Student's t-test. When applying this test to both groups, we obtain $p < 0.001$. Therefore, we can conclude that both groups experienced significant learning. Finally, we compared the post-test results for the two methodologies, determining that $p < 0.001$. Hence, we can conclude that in this learning experiment the group which interacted with the interactive whiteboard experienced more significant learning than the group who worked on paper. Figure 90 shows the evolution of the scores obtained in both groups, which helps to represent these results visually.
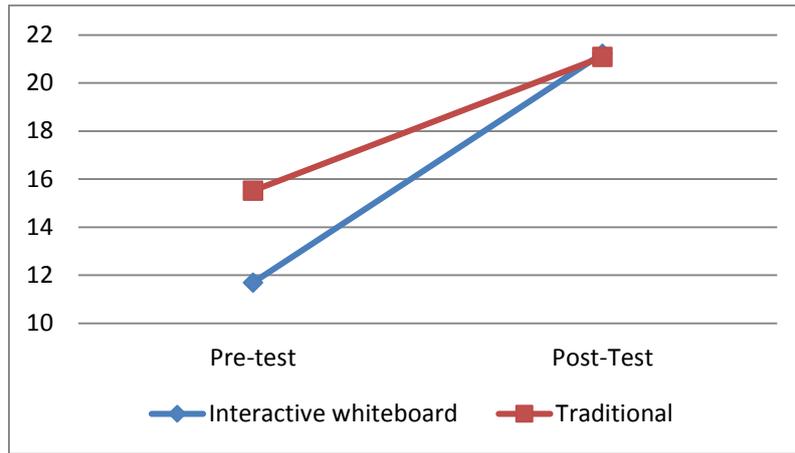
Figure 90. Primary education experiment, Mathematics evolution

8.5.2 Spanish Language and Literature

On the other hand, in the area of Spanish Language and Literature, 46 participants obtained better results on the post-test than on the pre-test, while two students had worse results. The maximum score possible was 47 points. By analysing the data from the tests, we can observe that the mean of the pre-test is 22.75 points and the mean of the post-test is 30.46 points. Figure 91 shows the general results obtained on both the pre-test and post-test.
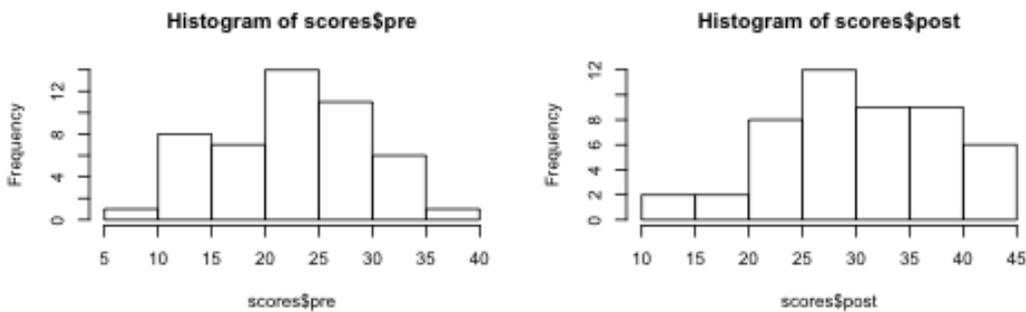
Figure 91. Primary education experiment, Pre-test and post-test results

As in the math activities, the next step was to check whether the students' learning was significant. To do this, we first applied the Shapiro-Wilk test to both samples to check their normality. For the pre-test samples we determined that p=0.43, while for the post-test this value was p=0.415. Since in both cases p>0.05, we can assume the normality of the samples. We then applied the Student's t-test to check whether there was significant learning. This test yielded p<0.001, so it can be concluded that significant learning took place.

Next, we present the results separated by group. In this analysis, we can observe that of the 22 students who solved the activities using an interactive whiteboard, only one did not obtain better results on the post-test than on the pre-test. This situation was replicated in the group that worked on paper, in which only one of the 24 students did not achieve better results on the post-test. Table 17 shows a summary of the results divided by group. The participants who used a traditional methodology started with a slightly lower knowledge level than the group with the interactive whiteboard. However, in this area the evolution of the participants of both methodologies is similar. The general evolution of both groups is shown in Figure 92.

Table 17. Primary education experiment, Results by groups for Spanish Language and Literature

		Interactive whiteboard	Traditional
Pre-test	Mean	24.04	21.34
	Median	25	22
	S. Deviation	7.78	6.01
Post-Test	Mean	32.28	28.47
	Median	33	29.5
	S. Deviation	8.77	5.61
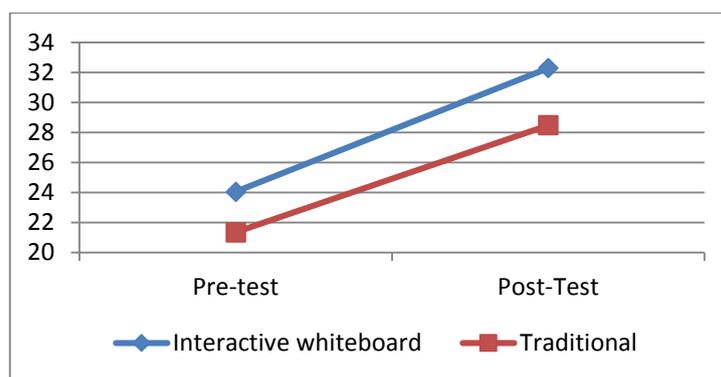
Figure 92. Primary education experiment, Spanish Language and Literature evolution

As in the area of Mathematics, to start comparing the samples we applied the Shapiro-Wilk test. This confirmed that the samples of both the group which used interactive whiteboards and the group which used traditional methodologies were normal. Therefore, we applied the Student's t-test, determining in both cases that $p < 0.001$. Hence,

both of the groups achieved significant learning throughout the experiment. Lastly, we analysed the results of both post-tests with the Student's t-test, obtaining a value of p=0.4391. Thus, in this case we cannot conclude that the technology group experienced more significant learning than the traditional methodology group.

8.6 Discussion

In contrast to the previous studies, in the experiments presented in this chapter the interactive whiteboard was mostly used by the teacher to do the educational activities, while the students guided him/her when choosing the answers. In this scenario, it can be said that the whole classroom comprised one large group, while the teacher was the one representing the ideas of the group on the interactive whiteboard. Although in this environment the students do not benefit from the direct interaction the device offers, as occurred in the childhood education experiments, the large size of the device helps the students to constantly be aware of the teacher's interactions and the status of the activity. Since all the students were aware of what was happening on the interactive whiteboard, it was possible to create an environment in which students wanted to participate and guide the user that was interacting with the application; this user was the teacher, in our case (see Figure 93).

Figure 93. Teacher doing a math activity on the interactive whiteboard

The methodology used in this learning experiment differs slightly from those presented in the previous chapter. In this study, there were two different classrooms and the students worked with different topics: Spanish Language and Literature and Mathematics. The experiment was set up in such a way that while one of the classrooms used the interactive whiteboard for the first topic, the other classroom used this device for

the second topic. By doing this, the motivation of the group was maintained and we were able evaluate the difference in learning among both groups.

Based on the analysis of the data from the previous section, we can determine than in both areas and in both groups, the results of the post-test were superior to those of the pre-test. In addition, this difference was almost double for Mathematics, and amounted to two points for Spanish Language and Literature. With these results, it can be concluded that the inclusion of technology in primary education could be a positive way to enhance learning and motivate students.

This motivation increases students' interest in the content, as seen in the childhood education studies. In this case, although the students were not directly interacting with the interactive whiteboard, their interest in the device and the content presented led to the creation of an environment in which students could discuss their answers while the teacher guided the discussions towards a common answer. This factor caused each of the students to feel important, since everyone had the opportunity to participate. Moreover, the teacher could motivate timid students; this task is more troublesome if students are divided into groups, since one teacher alone cannot be aware of every student at the same time.

On the other hand, although interactive whiteboards seem to be a useful tool for presenting content and promoting the creation of collaborative environments, teachers' comments indicate that even if technology is included in the classroom, this fact is not enough to change the traditional method of lecturing. It seems that the teachers who participated in this experiment were satisfied with the use of technology in the study, and have accepted that interactive whiteboards will increase motivation and change the way of interacting between teachers and students. However, our study shows that traditional teaching patterns, in which teachers stand at the front of the classroom, persist even if there is a device that students can interact with so that teachers can instead become guides in the learning process. On many occasions, this limitation arises due to time restrictions and software support of the topic they have to teach. In this regard, it seems that teachers want to adopt technology in a way that supports their teaching methodologies. This does not imply that they are opposed to changing any aspects of their methods. This could indicate that once technology is integrated in the teacher's methodology, this methodology can evolve. There is no need for a total revolution of teachers' digital competences (Bennet & Lockyer, 2008).

Still, the interactive whiteboard promotes certain changes related to the environment created within the classroom. Although they are usually controlled by the teacher, interactive whiteboards are a type of technology that is designed to be used by the whole classroom. In some moments during the experiment, students could participate in the routine and use this device. Students approached the whiteboard and were guided by their partner and the teacher during their interaction. The interactive whiteboard was the centre of attention of the classroom where all the actions took place, which helps to complement those situations in which activities are done in a more individual way. Taking into account that interactive whiteboards facilitate the inclusion of a wide range of content, it is possible to use them for various topics represented in our case by Spanish Language and Literature and Mathematics.

This study shows how interactive whiteboards offer immediate benefits to students. Moreover, as in the previous experiments, teachers were interested in how the use of technology could assist them when preparing lessons and presenting digital content. This means that teachers could use digital resources available on the Internet or other sources, and also use their own created content. The ability to present activities and instruction on the whiteboard helps teachers to save time, for instance since they do not have to photocopy resources for each of their students. Digital content which is prepared can be quickly shown on the screen, which means that teachers do not have to write too much themselves; this makes the lessons smoother and the transition between them faster. This is one of the possible features that caused the teachers who participated in this experiment to be more satisfied with the use of this device.

All of the advantages offered by the interactive whiteboard have positively translated into an enhancement of students' learning. In both Mathematics and Spanish Language and Literature, the students who worked with the interactive whiteboard had better results on the post-test than on the pre-test. The study has shown that students who were lectured using the interactive whiteboard were motivated at all times, while the students who worked with paper were not as motivated. However, although the increment was notable in both areas, this increase was only significant in Mathematics. Thus, it is necessary to carry out more studies in this educational level to shed light on the impact of technology in primary education.

CHAPTER 9: SPECIAL NEEDS

According to the studies in the literature conducted with students with intellectual disabilities (Rosado-Martín, 2013; Rosado-Martín et al., 2013) and students with ASD (Márquez-Fernández, 2013), touch devices offer an appropriate environment for learning and knowledge transfer since they eliminate the need for intermediate peripherals such as a mouse or a keyboard, thus allowing the students to focus on the learning elements (Hourcade et al., 2013; Roldán-Álvarez et al. (b), 2016). Accordingly, we used multi-touch tabletops for the two studies carried out in this area, as these devices offer a collaborative workspace in addition to eliminating the need for the abovementioned peripherals. This chapter first presents an experiment with students with ASD, followed by an experiment with students with intellectual disabilities (Roldán-Álvarez et al. (a), 2016; Roldán-Álvarez et al., 2014).

9.1 Educational experiment with children with Autism Spectrum Disorder (ASD)

In this learning experiment, students with ASD had to solve an educational project in pairs while taking turns using a multi-touch tabletop. We adapted the interface of DEDOS-Player so that the player areas followed an 'L' shape (both students worked in the same corner of the table), which was the normal way of working at the institution. We also included auditory and visual supports to improve knowledge acquisition and prevent excessive variation from the students' usual methodology.

9.1.1 Participants

This study involved the participation of the Leo Kanner Special Needs Education institution of Madrid. There were eight participants (seven male and one female) from 9 to 19 years old. All the students were diagnosed with General Development Disorder (GDD) of autism type except one, for whom we did not have concrete information. The participants presented low functionality and a degree of handicap between 33% and 65%. All the students were able to read, but presented different levels of reading comprehension. Only three of the participants belonged to the classroom where the study was carried out. This factor was important, since the other five students were more distracted, as described in the following paragraphs. Table 18 shows the profiles of the students who participated in this study, with the column 'Classroom' indicating which of them belonged to the classroom where the study was conducted.

Table 18. Special needs education, Profiles of students with ASD

Participant	Age	Diagnosis	Handicap	Reads	Classroom
P1	13	GDD, autism	Not available	Yes	Yes
P2	19	GDD, autism	65%	Yes	No
P3	10	GDD, autism	41%	No	No
P4	11	GDD, autism	44%	Yes	Yes
P5	9	GDD, autism	Not available	Yes	No
P6	11	GDD, not specified	40%	No	No
P7	10	GDD, autism	33%	No	No
P8	11	GDD, autism	53%	Yes	Yes

9.1.2 Educational Project

For this project we designed activities in collaboration with the pedagogical team of the institution, which supervised the study at all times. The teachers provided several instructions to establish the goal of the educational activities. Firstly, the topic to work with was theory of mind (ToM) and language and communication. Specifically, the activities aimed to emphasise emotion recognition, a troublesome area for people with ASD. To avoid frustrating situations, the activities were combined with daily life activities, which is an easier subject area. Secondly, the activities had to contain real images without distracting elements, in order to clearly show the corresponding emotion or action. Moreover, to ease the students' comprehension of the activities, we added pictograms from ARASAAC[6] to elements that would initially only have text.

The project was composed of 17 multiple-choice activities in which students had to choose one or more answers, along with pair-matching activities in which students had to associate several concepts. Figure 94 shows an example of an activity about emotion recognition and an activity about daily life activities.

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[6] http://arasaac.org/

Figure 94. ASD, From left to right: Activity about emotion recognition and activity about daily life activities

9.1.3 Measurement instruments

In this educational experiment, we wanted to measure the following: the participants' evolution throughout the study (number of activities completed in each session, number of right answers and amount of support needed); and whether they felt more comfortable using the multi-touch tabletop as they progressed through the sessions.

Another factor that we intended to study was whether taking turns to interact helped students to be aware of their peers' interactions and more conscious about what was happening around them. Therefore, students solved the activities in pairs using this interaction dynamic. By applying direct observation techniques with the support of two observers who were present in all the sessions, we were able to take notes about the participants' behaviour. Through these notes, we gathered information such as each participant's attitude and the interactions he/she had with the multi-touch tabletop.

Lastly, we wanted to study the performance of the participants in the two areas they worked with: theory of mind and daily life activities. We believed that the participants would have more difficulties with theory of mind activities, meaning they would complete fewer answers about this topic and would need more support in order to solve them.

9.1.4 Methodology

This study was carried out in seven sessions over three consecutive weeks (on Mondays and Tuesdays), with an additional day in the last week. The methodology is described in the following.

In the first week, the study was carried out individually so that the students would become accustomed to the multi-touch tabletop and therefore familiarise themselves with the gestures and the types of activities they would have to solve.

With the goal of teaching the students to wait for their turn to interact, and to see whether they were aware of their partners' interactions, the second and third weeks' sessions were carried out in pairs, following the criteria of the pedagogical team of the institution.

Since the participants always solved the same project, during the third week we altered the order of the activities. This change made the students work on the last activities, since in the previous sessions they sometimes did not have time to reach these.

9.1.5 Evaluation

The results of the evaluation are divided into two sections: data gathered through quantitative analysis of the activities done, as well as the successes and support in each of the sessions; and data gathered through direct observation.

9.1.5.1 Quantitative evaluation

Firstly, this section describes the results of the number of activities completed in each session. We believed that the students who belonged to the classroom where the study was carried out would complete more activities than those who did not belong to the classroom, since they were more familiar with the environment. Moreover, as each session advanced, we thought there would be an increase in the number of activities completed since all the students would become accustomed to the work environment. Figure 95 presents a graph of this information. The participants are shown on the X-axis, while the Y-axis represents the number of activities completed. Each bar represents one session. It should be noted that some of the participants took part in an additional session.

We can observe an increasing tendency in the number of activities completed, although there are some exceptions. For instance, participant P8 finished all the activities in the first session, but he/she was unable to complete half of the activities in the second. This is because when interacting in pairs, participants depended on their partners; this can lead to a decrease in performance if the partner spends more time solving the activities.
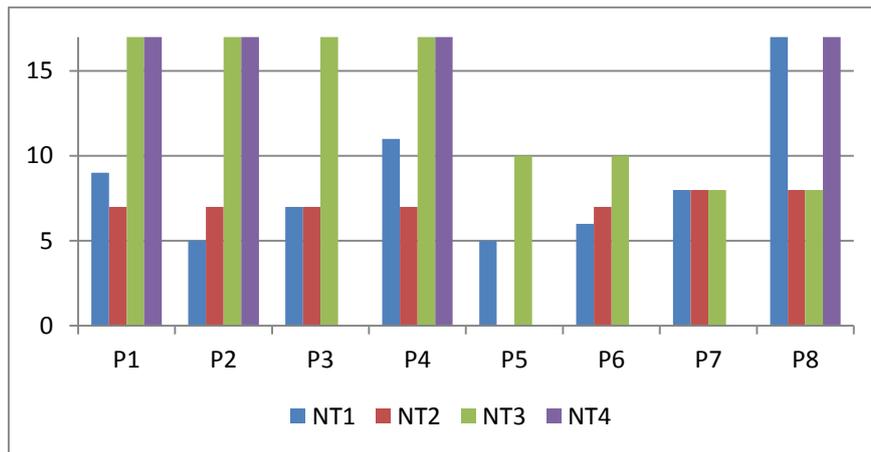
Figure 95. ASD, Number of activities completed per session

Figure 96 shows the results of the number of activities solved correctly by the participants in each session. Only those activities finished by the participants are taken into account, so activities that were not completed by the participants do not count for this score. As in the previous figure, a positive evolution can be seen in the number of correct answers from the students, in some cases reaching 100%. In this case there are three exceptions, corresponding to the students P5, P6 and P7, who showed an irregular evolution. This was due to their nervous attitude and how easily they became distracted.
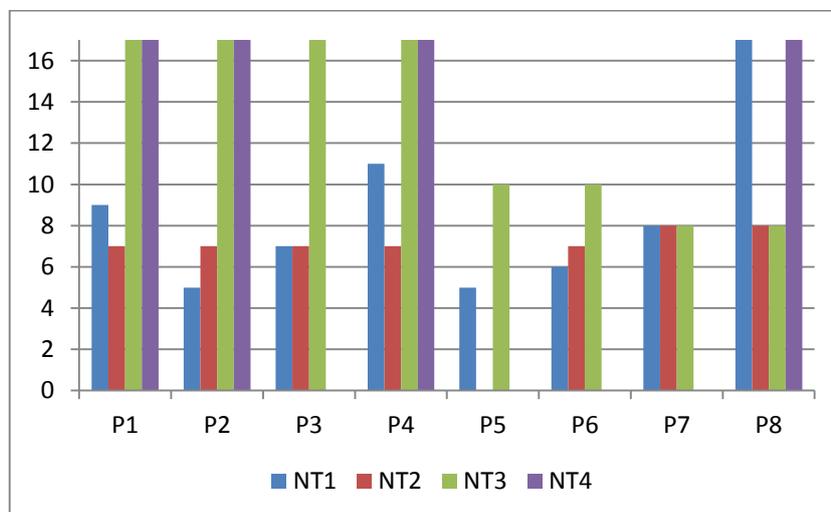
Figure 96. ASD, Number of correct answers

Lastly, in this study we measured the amount of support needed by the participants to complete the activities. Support is considered to be any help that the pedagogical team offered to the participants to help them to complete an activity. Since the first session was a familiarisation, session we decided not to show the results related to that session. Figure 97 shows the number of times support was needed by each participant in the second, third and fourth sessions. In this graph, the number decreases each session. On the other hand,

the participants in the fourth session also needed less support, although this decrease is not as significant as in the second and third sessions.
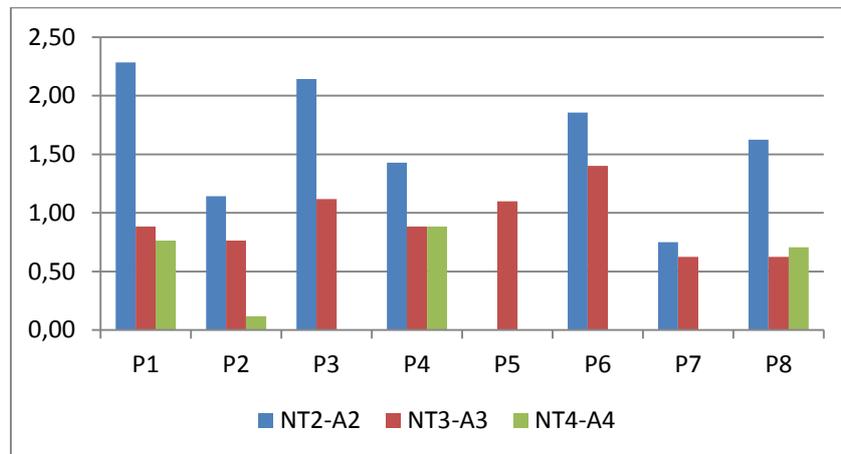
Figure 97. ASD, Number of times support was needed per activity and session

If we go deeper into the number of times support was needed and the answers given in each activity, divide these according to the activity topic, we can observe that in theory of mind activities (see Figure 98) there was more support than in activities about daily life activities (see Figure 99). Moreover, comparing the correctness of the answers, we can see that some participants had trouble answering correctly. This shows how difficult it is for people with ASD to recognise emotions. However, it is also clear that there is a decrease in the amount of support needed and an increase in the success rate as the sessions passed.
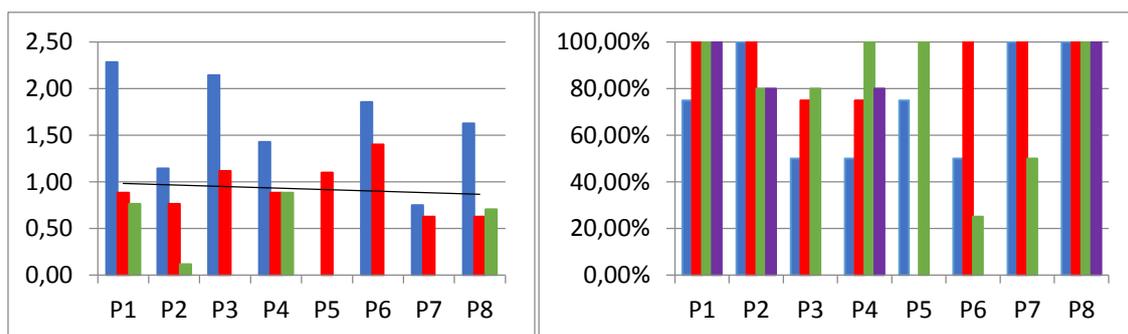
Figure 98. ASD, Support needed and number of correct answers in theory of mind activities
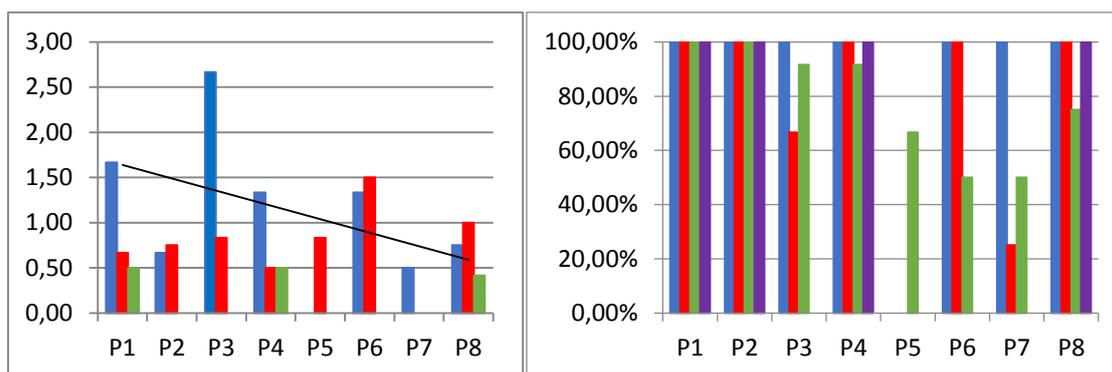
Figure 99. ASD, Support needed and correct answers about daily life activities

9.1.5.2 Direct observation

During the first session of the study, participants P1, P2, P3 and P4 showed a good attitude, although in the beginning they were distracted since it was the first time they had interacted with a multi-touch tabletop. While the students' interest in the device increased throughout the sessions, their performance was not satisfactory since they did not solve many activities. On the other hand, participants P5, P6 and P7 did not have a good attitude and were nervous throughout the sessions. This happened because none of these three participants belonged to the classroom where the study was being conducted. This factor caused P5 not to complete any activities, and P6 and P7 to only complete half of them, even after receiving support from their educators multiple times. On the other hand, P8 completed all the activities, and was the only one to achieve this in the first session.

In the second session, students started doing the activities in pairs. Although in the beginning participants P1, P2 and P4 were not focused, this did not influence their overall performance in this session. On the other hand, P3 was restless and did not calm down until the educator asked him/her to. These participants solved the activities quickly and with less support, so they ended up increasing their number of activities solved compared to the first session. It should be pointed out that P2 and P4 were aware of their peers' interactions. Regarding participants P5, P6 and P7, their attitudes became worse. P5 did not complete any activities, P6 was easily distracted and P7 was nervous. Only P8 showed the same attitude as before and completed all the activities.

In the third session, the behaviour of P1, P2 and P4 was good and their interest increased. However, P3 was nervous, and the educators had to take him away from the tabletop in order to calm down. During this session, these participants showed a notable evolution regarding the understanding of the taking turns dynamic and the awareness of

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their partners' actions. This factor helped them to complete more activities since they did not need as much support as before. In this session, participants P5, P6 and P7 were disrupted, although P5 improved his behaviour throughout the session. The nervousness of P7 caused P8 to become tired and stop doing the activities.

During the additional day, the educators chose participants P1, P2, P4 and P8 as the participants with the best attitude through the study. Their general behaviour was good, as they respected each other's turns and were aware of their partners' actions at al' times. In this session, the pair P4 and P8 did not work as well as expected due to the nervous attitude of P4 and his/her slowness when solving the activities. Because of this, this pair needed constant support since the attitude of P4 cause P8 to adopt a rebellious attitude. Nevertheless, P8 completed all the activities.

9.1.6 Discussion

In this experiment, we had the participation of several professionals who went from the pedagogical team to the technical team, creating a multidisciplinary group which eased the integration of ICT in the classroom of students with ASD. Due to the target population of this study, it was necessary to develop a detailed design of the activities that would be solved by the students; these activities had to be completely adapted to them (Roldán-Álvarez et al., 2014).

One of the differences of this study is that the students used a multi-touch tabletop, as the device's the horizontal position and touch interaction seem appropriate for students with ASD. The use of this new technology sparked the curiosity of the participants, which translated into an enhancement of their attention towards the content presented. In this regard, it was observed that the participants learned the interaction gestures with the multi-touch tabletop quickly, learning to move, choose and rotate elements autonomously (Tartaro et al., 2008). However, there were some interaction issues due to the hardware, which were solved by the use of a mouse to simulate the participants' gestures as they were making them.

If we analyse the learning process of the participants, it can be observed that the participants learned about the topics addressed in the activities. This can be stated because of the students' evolution in the number of activities completed and the number of correct answers given throughout the sessions. Moreover, the number of times support was

needed in order to solve the activities decreased each session, which indicates that the students were more autonomous and completed the activities without external help.

One of the most interesting results of this study is the clear influence of the place where the study was carried out. Those participants who did not belong to the classroom where they solved the activities were more distracted, nervous and distant than those who belonged to the classroom. It seems that a factor to take into account is that students are accustomed to their usual working environment, which is key for them to feel calm and therefore able to focus on the activities. This fact was reflected in the number of activities completed by each of the participants, which was greater for those who belonged to the classroom. In order to enhance students' performance and avoid distractions, it is recommended to familiarise them with the place where they will work and with the people they will work with (Grenier & Yeatom, 2011).

Throughout this study, we also observed an increase in the number of interactions among the participants. From the second session onwards, interaction among peers increased when the participants started working in pairs, especially in the third and fourth sessions. It seems that the visual and auditory supports included in the application encouraged students to interact with each other and to show certain social skills which had not been seen before, such as respecting each other's turns and helping their partners to choose the right answers (Hailpern et al., 2009). In this regard, completing the activities in turns helps to achieve this goal since it makes students think and look at what is happening on the tabletop, thus enhancing their awareness.

Finally, we detected the need to differentiate the type of activity the students must solve. In this experiment, we observed that participants tended to repeat the same gesture as in the previous activity. For instance, if they first solved a multiple-choice activity and then a pair-matching activity, in this second activity they performed the select interaction instead of the drag and drop interaction. To avoid this kind of problem, there are several possible solutions: clearly explain in the question of the activity what type of interaction the student must perform, modify the application so that both types of activities are clearly differentiated, or do not combine multiple-choice and pair-matching activities in the same educational project.

The data gathered from this learning experiment shows that people with ASD are able to learn to use touch technology. The students learned to interact independently with the multi-touch tabletop throughout these sessions, and their performance improved as

they became accustomed to this device and to the workplace. Moreover, the use of a multi-touch tabletop and pair-based interaction led to knowledge gain as well as enhanced use and development of social skills, which are essential in these students' daily lives. Little by little, students went from solving the activities individually to helping each other solve all the activities.

9.2 Educational experiment with children with Autism Spectrum Disorder (ASD)

As in the previous study, students had to solve educational activities on multi-touch tabletops. Furthermore, in this experiment we wanted to study whether interacting by using turns is more beneficial for the students' learning process than simultaneous interaction when solving activities in groups of three or four students. When interacting using turns, students can be more aware of their partners' actions. This could mean that they would not only learn through their actions, but also through their partners' interactions.

9.2.1 Participants

This study involved 52 adult students with intellectual disabilities from the Down Syndrome Foundation of Madrid, including 19 men and 33 women. As stated in the second chapter of this document, people with intellectual disabilities present difficulties when retaining information. Accordingly, it is important that the concepts are presented to them in a visual, simple and repeated manner so that they can achieve significant learning.

9.2.2 Educational project

The educational activities in this study were about musical instruments, since this topic was not included in the curriculum of the institution. Accordingly, we expected the students to start from a low level of knowledge so that we could measure their evolution throughout the study. Because people with intellectual disabilities learn better through visual elements, we looked for real images of musical instruments when designing the activities. These images had to fulfil several requirements: they had to be real and in colour in order to favour knowledge transfer, and had to be oriented in a way that it facilitated their recognition.
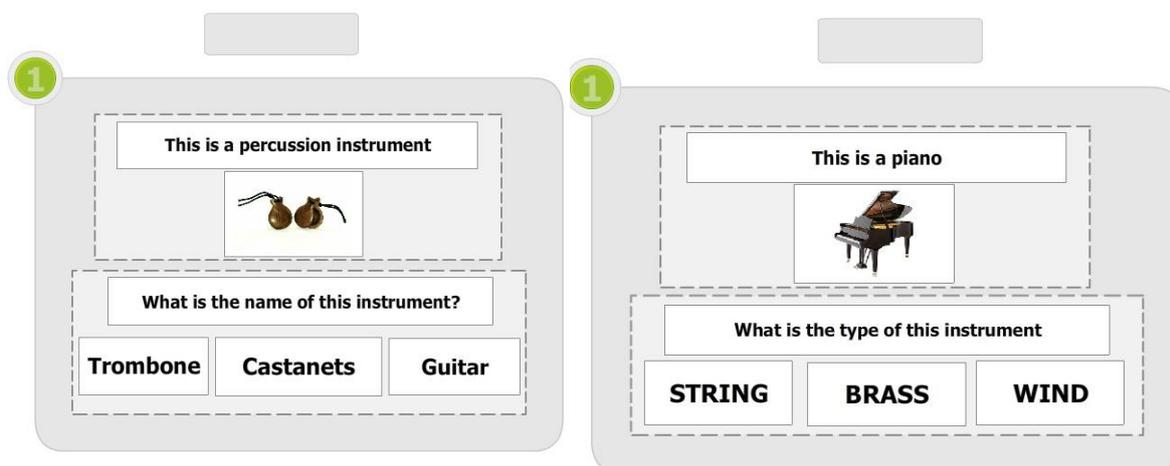
Figure 100. Intellectual disabilities experiment, Examples of activities

For this study, only multiple-choice activities were designed in order to avoid interaction issues with the multi-touch tabletop. This is because the drag and drop movement is physically more complex, and some of the participants presented motor disabilities. In total, there were 48 activities divided into three types: name recognition (see Figure 100), type of instrument, and either of the previous two without visual support. The activities were structured in two different projects which covered different musical instruments. We tried to avoid the inclusion of distracting elements in the activities at all times by designing clear and focused activities with a supplementary explanation and an image to better express the goal of the activity. As in the previous experiment, the design and creation process was supervised by the pedagogical team of the institution.

9.2.3 Methodology

Once the activities were designed, we composed the groups. Since the participants' skills varied greatly, we decided to form groups as homogeneously as possible so that each of the groups would have a similar knowledge level. In order to classify the participants and form the groups, we used the Reynold Intellectual Assessment Scales (RIAS) test (Reynolds & Kamphaus, 2003) with the goal of obtaining indicators such as the intellectual coefficient. This test can be applied to a wide range of ages (from 3 to 94 years old). The duration of this test is approximately 40 minutes, and the educators were in charge of evaluating the students and forming the groups. In total, the 52 participants were divided into 16 groups of three or four members each.

This study was carried out over two weeks, during each of which we worked with a set of students from the institution. Taking into account the difficulty these students

present when retaining information over time, we decided to hold three sessions during the same week (Monday, Wednesday and Friday). Overall, eight groups completed the experiment during the first week, and the other eight groups participated during the second week.

On the first day of the experiment (Monday), participants had to complete a pre-test. Then, they performed the activities on the multi-touch tabletop, dealing with eight musical instruments: castanets, flute, maracas, saxophone, piano, drum, triangle and bandurria. For each instrument there were three types of activities, so participants had to complete 24 activities in total.

During the second day of the study (Wednesday), participants worked with a different set of instruments: violin, xylophone, banjo, bell, tuba, gong, guitar and harp. As in the previous session, they had to complete 24 activities.

Lastly, during the third session (Friday), the participants only had to complete a post-test so that we could evaluate whether they experienced significant learning due to the experiment.

One key factor of this study was that not all the groups used the same interaction dynamic to complete the activities. Some of the groups solved the activities using turns, which means that one participant cannot complete his/her activity until the partner whose turn it is has finished (see Figure 101). Other groups used a simultaneous mode of interaction (see Figure 102), in which all the participants can solve the activities at the same time. Finally, other groups used a mixed interaction dynamic, in which they interacted by taking turns during the first session and working simultaneously during the second, and the other way around. We made this division in order to study whether the interaction dynamic impacts the learning process, and whether it enhances the participants' awareness.

Figure 101. Intellectual disabilities experiment, Turns

Figure 102. Intellectual disabilities experiment, Simultaneous

9.2.4 Measurement instruments

As mentioned previously, before the participants started doing the activities on the multi-touch tabletop they had to complete a pre-test to determine their previous knowledge about musical instruments. This pre-test included 16 activities with questions about the name and the type of the instrument. Once the experiment ended, the participants had to complete a post-test which contained the same questions.

Apart from the pre-test and post-test, DEDOS-Payer registered the student's interactions with the application in a file. Specifically, it stored information about the activity they were doing, the number of players, the interaction dynamic, the answer of each player and whether or not the answer was correct.

In order to complement this file, we also took notes through direct observation. For this purpose, there were three or four observers in each session who took notes about the attitudes and actions of the students.

9.2.5 Evaluation

After carrying out the study, we proceeded to analyse the results extracted from the pre-test and post-test, the data of the logs generated by DEDOS-Player, and the complementary data from the notes taken through direct observation.

9.2.5.1 Test analysis

In order to analyse whether significant learning occurred among the participants, we evaluated the results of the 16 activities that composed the pre-test and post-test. We believed that the initial knowledge level would be low. Moreover, we wanted to confirm

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whether the interaction mode used by the students when solving the activities affected their learning process. In particular, we expected to obtain a better result for those students who worked using turns, since that dynamic better exploits the advantages of collaborative learning and enhances students' awareness. It seems that making the students wait for their peers to finish the activity causes them to use that time to think about the answer they will give when their turn comes. In addition, they have access to the feedback offered by the application to their peers.

Figure 103 shows the mean results of the pre-test and post-test according to the interaction dynamics. An improvement can be observed in the results of every interaction dynamic. However, the improvement is greater in those students who interacted using turns.
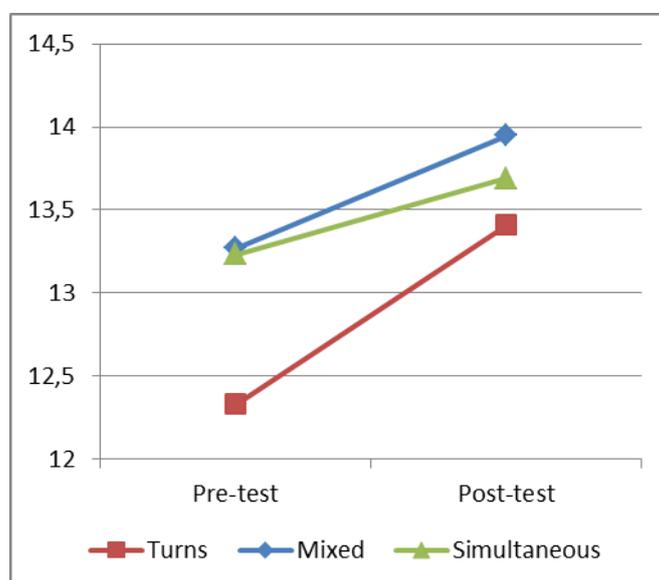
Figure 103. Intellectual disabilities experiment, Results of pre-test and post-test according to interaction dynamic

In order to check whether the results of the three interaction types were significant, we used the Student's t-test since all the samples follow a normal distribution. After each of the tests, we observed that the difference when using turns and when using a mixed interaction method was significant ($p<0.05$), while when interacting simultaneously it was not ($p=0.15$). We can conclude in this study that the hypothesis predicting that turn-based interaction can favour students' learning in comparison to simultaneous interaction is true.

9.2.5.2 Evaluation of the awareness of peers' actions

After determining that the interaction mode impacts students' learning, we wanted to evaluate whether interacting using turns encouraged participants' awareness of their peers' actions. Firstly, we examine whether the order in which a participant gives an answer is important. Table 19 shows the number of successes and failures according to the position in which the participant gave the answer, divided based on the interaction dynamic used. It can be seen that when students interact using turns, the number of correct answers increases and the number of wrong answers decreases as each turn passes; this causes the student in the last position to have a greater percentage of right answers and a lower percentage of wrong answers than his/her peers. However, when interacting simultaneously, the number of right answers and wrong answers is similar across all positions. Moreover, it should be noted that the fourth row of this table has less data since there were fewer groups with four participants. The columns represent the successes and failures according to the last answer given by the student in the position represented in the row. The numbers between brackets that appear in Table 19 represent the number of correct cards and the number of incorrect cards selected by the students. It should be taken into account that when interacting using turns, the number of successes and failures are not counted until the participant checks the activity.

The analysis of the data confirms that when using turns, the order and position of the student when giving an answer influence the answer success (X^2 (3, n=1034) = 12.65, p<0.05). Therefore, if answering first, the student will give more wrong answers than those in the remaining positions. It was observed that in this dynamic, students who answer last usually copy their peers, thus making fewer mistakes.

Table 19. Intellectual disabilities experiment, Successes according to the position of the participant when answering

	TURNS		SIMULTANEOUS	
	Right	**Wrong**	**Right**	**Wrong**
1	78.84% (272)	21.15% (73)	89.13% (328)	10.86% (40)
2	85.21% (294)	14.78% (51)	89.67% (330)	10.32% (38)
3	87.24% (260)	12.75% (38)	87.15% (319)	12.84% (47)
4	95.55% (43)	4.44% (2)	84.44% (38)	15.55% (7)

On the other hand, the percentage of right and wrong answers in the simultaneous mode is similar across all the positions. After analysing the sample (X^2 (3, N = 1147) = 2.015, p = 0.57), it can be confirmed that the order in which the students answer does not affect the outcome of the answer. Since the participants were able to interact at the same time, they did not look at their peers' answers in the same way as occurred when interacting using turns. However, when students interacted using turns, they tended to look at what their peers did and usually copied their interactions. This does not necessarily imply that the student will always choose the right answer when copying, since in some cases the students copied wrong answers. This scenario can be seen in the data presented in Table 20.

Table 20. Intellectual disabilities experiment, Consensus among students

	ALL RIGHT	**ALL WRONG**	**OTHER**
TURNS	70.14% (242)	4.92% (17)	24.92% (86)
SIMULTANEOUS	75% (276)	2.44% (9)	22.55% (83)

9.2.6 Discussion

In the education institution of students with intellectual disabilities, we encountered a different scenario to that experienced in the previous experiments. The pedagogical team of this institution used technology often, so their knowledge about technology was high. This factor meant that the students were accustomed to working with technology, guided by teachers who said that ICT helped to attract the attention of this kind of students. As in the study with students with ASD, the device used was a multi-touch tabletop.

The study presented in this section helps to validate that multi-touch tabletops can be used satisfactorily by students with intellectual disabilities (Roldán-Álvarez et al., 2014). This new technology awakens the curiosity of the students by capturing their attention in a remarkable way. We wanted to increase this attention through the creation of varied educational activities which promoted the transfer of knowledge from the application to the real world. To do this, students worked on musical instrument concepts. For this purpose, we used real images which represented each of the instruments in the activities' design, and we avoided any distracting elements (Aditya et al., 2016), as in the study with students with ASD.

Although in the first session the students had some interaction problems since it was the first time they had interacted with a multi-touch tabletop, throughout the sessions they learned how to interact with the surface and work independently. The horizontal layout of the multi-touch tabletop and the method of working in groups caused the students to give more right answers and to interact more with their peers as the sessions progressed. This was mostly due to their awareness of each other's actions.

In this study, the students' awareness was analysed at all times. While working in groups around a device can enhance this awareness, in the experiments presented in Chapters 7 and 8 in which students used an interactive whiteboard, there was only one workspace and all the students interacted with it. Consequently, all the students gave the same answer even if only one student chose it, since they were working with the same content. In this environment it was impossible to analyse whether peers' actions influenced students' personal decisions. This is why, in the experiment with students with intellectual disabilities, the participants worked on a multi-touch tabletop and the activity was replicated according to the students who were around the tabletop. For instance, if a group of four students was doing the activities, each student would have their own workspace. Moreover, and differently to the study with students with ASD who only worked using turns, we included several groups which worked simultaneously without having to wait for their peers to finish the activity. This configuration allowed for a deeper analysis of whether the interaction dynamic affects users' awareness of each other's actions.

In this respect, and as other authors have highlighted in the literature, the mode in which the user interacts with the application remarkably impacts their learning process (Rogers et al., 2006). In this study, we observed that students who worked using turns achieved significant learning according to the test results. When interacting in turns, students must wait for their peers to finish the activity; this causes them to look at their peers' movements and think about the answer they will give when their turn comes.

Although the data gathered from this experiment indicates that the students who worked using turns experienced significant learning, it should be highlighted that students in this dynamic also gave more wrong answers. This is due to the fact that, when working using turns, there were many times when the students directly copied their peers' answers, even if these were wrong. This occurred because the students' learning approach is usually based on copying and repeating. This situation was not replicated by the groups which

interacted simultaneously, since they seldom looked at their peers' interactions and therefore were not aware of their partners' answers.

For the groups which interacted by turns, were also analysed whether the order in which the student gave the answer impacted the answer outcome. In this case, the results gathered confirm that the order in which the student gives the answer influences their success. The data shows that while the student who answers first fails in 21.15% of the activities, the student who answers last only answers incorrectly in 4.44% of the activities. This situation suggests that as the participants answer and the turn goes to the next participant, there are a greater number of answers that guide the student when choosing the correct one. This implies that while the first participant does not have any kind of feedback when solving the activity, the last student has the opportunity to look at the answers his/her partners have given so that he/she can consider these answers and the feedback that the application has given.

Summarising the results obtained in the study presented in this section, it can be stated that after using the multi-touch tabletop, the students demonstrated greater knowledge about the concepts they worked with. This increase was more significant in the group which worked using turns. In addition, participants quickly learned how to interact with this kind of surface. This made it possible for the students to achieve the goals established by their educators more quickly and without the need for constant support. Finally, it was observed that interacting on a multi-touch tabletop using turns remarkably enhances students' awareness of their peers' interactions.

CHAPTER 10: CONCLUSIONS

In this chapter, the conclusions of this work are presented. Firstly, the contributions derived from this work as well as its benefits and limitations are shown. Then, current and future work is described. Lastly, the publications of this work are listed, along with its awards and dissemination activities.

10.1 Contributions

This work has focused on providing tools that allow teachers to design and customise their own educational activities so that students can perform them on a wide range of devices, including tactile devices which have burst into the educational sector. Thanks to these applications, teachers can transform into facilitators of their own digital content which can be accessed by students on any devices, both in the classroom and at their homes. The content is automatically adapted to the device being used, without the need for teachers to make any adjustment to the device setup. Moreover, the possibility to change several configuration parameters allows teachers to adapt education projects to their pedagogical needs as well as to their students' needs, creating a wide range of learning experiences which can be either individual or collaborative.

DEDOS-Editor allows educational activities to be created through direct manipulation and following a consistent creation metaphor, which is new in the market with DEDOS-Player and DEDOS-Web. With the definition of D2XML, it is possible to develop third-party players that run activities designed with DEDOS-Editor. DEDOS-Player is a desktop application that enables educational activities designed with the authoring tool to be run on various devices, such as personal computers, interactive whiteboards, tablet computers and multi-touch tabletops. To take advantage of the benefits of using DEDOS-Player as well as the growing connectivity of educational institutions and current devices, DEDOS-Web was implemented. This application is located in the cloud, and allows teachers to manage their projects and students without the need to install any software on their devices.

Some of the most prominent problems when using technology in the classroom include the lack of use of both the software and hardware available, as well as the lack of technological knowledge among teachers, as described in Chapter 2. In this work, the authoring tool provided is flexible enough to enable teachers to become the designers of their own activities which can be used in the classroom according to their goals. To

achieve this, it was necessary to evaluate whether users were able to create content in a simple and easy way. To this effect, the ease of learning of DEDOS-Editor was studied, comparing it to the most popular authoring tool in Spain: JClic-Author. The results show that a direct manipulation paradigm and a consistent creation metaphor allow teachers to learn to use one application faster than those with menu-based applications.

The flexibility of DEDOS-Editor enables teachers to design activities for any educational level, and allows several types of activities to be combined in order to design more complex activities. Other authoring tools do not facilitate this combination; for example, if a multiple-choice activity is designed, it is not possible to add pairs to that activity. However, through DEDOS-Editor it is possible to combine different types of goals by dragging and dropping these onto the corresponding cards, without the need for any complex operations.

Furthermore, DEDOS-Player allows teachers to configure additional parameters according the pedagogical goals they wish to achieve, as detailed in Chapters 4 and 5. This means that teachers can create several learning scenarios with the same digital content, without having to use the authoring tool each time he/she wants to change these parameters. This also facilitates the sharing of educational projects since teachers will not have to worry about previous configurations, as these can be selected when starting DEDOS-Player. However, since DEDOS-Player needs to be installed on each device and teachers would not be able to easily analyse their students' results, we decided to develop DEDOS-Web. This platform retains the functionality of DEDOS-Player, but also allows more organised management of projects, students and results. Since DEDOS-Web runs on the cloud, it was possible to integrate a learning analytics service with that application, which can obtain and process all the information from the main service and send it back upon teachers' request. This allows teachers to access students' results at any moment through any device. Thus, teachers could use educational methodologies such as 'just-in-time-teaching' (a pedagogical strategy that uses feedback between the class activities and the students' work at home to prepare lectures), an approach which is not supported by many of the existing authoring tools.

The studies conducted with students from the degrees in Childhood Education and Primary Education, and current students of childhood education, primary education and special needs education, shed light on: a) how the graphical user interface of an authoring tool influences the learning curve of an application; b) the knowledge gain when

technology is included in the classroom; c) how technology enables the creation of collaborative environments; and d) how touch technology facilitates the integration of ICT in classrooms with students who have underdeveloped motor skills.

Students from the degrees in Childhood Education and Primary Education who participated in the first study noted their preference for DEDOS-Editor over JClic-Author, suggesting that this tool should be included in the subject 'ICT in Education'. This fact is underscored by the way in which all the participants easily learned to use DEDOS-Editor, even without having any information about the tool. However, despite having used JClic-Author prior to the study, the participants encountered many issues when trying to finish the activities. In this scenario, participants chose direct manipulation and a consistent creation metaphor; this differs from the typical guided menus, which reduce the flexibility of a tool and prevent concepts learned when creating one activity from being used to create another type of activity. According to the participants' opinions, they were satisfied with the use of DEDOS-Editor, a tool that allowed them to quickly design educational activities by the end of the study.

Regarding the studies conducted with students of childhood education, it must be mentioned that at the start of the experiment the teachers opposed to the use of technology by young students. We believe that this scepticism was due to the teachers' existing prejudices about technology, as other authors have stated in the literature (Lindahl & Folkesson, 2012). On the other hand, students showed a great interest in the use of tablet computers and interactive whiteboards, which translated into higher motivation compared to the students who solved the activities on paper. Little by little the teachers noticed this, observing their students collaborating among themselves and using the available devices independently. These features were complemented by the good results obtained by the students who worked with technology, thus changing the teachers' perspective about the use of technology in the classroom.

A similar situation occurred in the study with students of primary education, where the group using the interactive whiteboard was more satisfied than the group which solved the activities on paper. This study focused on two areas, Language and Literature and Mathematics, with two groups. This made it possible for one of the groups to use the interactive whiteboard in the first experiment, while the other group used the interactive whiteboard in the second. Because of this change, the general level of motivation was maintained in both groups. Although in this study the teacher was the one who used the

interactive whiteboard, the visibility that this device offers when presenting content enabled the teacher to solve activities dynamically with the help of the students, who were always eager to participate. Teachers valued this experience positively, noting that the interactive whiteboard improved participation in the classroom.

Regarding special needs students, we found that they were accustomed to using technology. Additionally, the pedagogical team of the institution had knowledge about technological devices such as digital tablets and interactive whiteboards, regularly utilising them to perform activities with their students. As a result, the introduction of multi-touch tabletops in both experiments was not problematic. This device was well received by students with cognitive disabilities, and although students with Autism Spectrum Disorder had some issues with the tabletop in the first session, they learned how to use it by the second session. Thanks to the multi-touch tabletop, the pedagogical teams of both institutions saw how this device enhances interaction and collaboration among the users located around it. Moreover, it was observed that even if some of the students presented a lack of development in their motor skills, they did not have any issues when interacting with the tabletop.

As general conclusions, these studies show that the graphical user interface of an authoring tool concretely impacts its learning curve, which affects how quickly and easily the users will learn to use the tool to design their own educational activities. The flexibility of DEDOS-Editor facilitates its use in different learning levels and for different topics, which allowed all the studies presented in this document to be carried out. In these studies, the participants who used technology were more motivated and more eager to participate than those who solved the activities on paper, who worked individually without worrying about their peers. Due to these features and the good results obtained by the participants, we believe that the teachers' scepticism was reduced, leading them to reconsider the use of ICT for their lectures. ICT's accessibility – and touch technology in particular – allows students of any age, including those with special needs, to use technology without any issues.

10.3 Current and future work

Currently, we are working on providing a more complete learning analytics service for DEDOS-Web. As part of this effort, simplifying the data stored in the application to present it visually and in a simpler way is one of the priorities in order to

improve DEDOS-Web. This is a determining feature, since the ease with which teachers can interpret the information they receive about their students' use of the application will help them to evaluate their students' performance.

It could also be important to add new types of activities to DEDOS-Editor. Although the activities that can be designed in DEDOS-Editor cover approximately 70% of the activities that teachers want to create (multiple-choice and pair-matching), it would be interesting to include other type of activities such as puzzles and sequencing activities. These types of activities would complement those already available, and transform DEDOS-Editor into a more powerful tool. However, the creation of these activities should follow the consistent creation metaphor defended in this work, so that their implementation will not be trivial. In addition, and related to the previous section, the possibility of including audio with the cards or creating an audio card itself will be studied. After all the feedback received by the participants of the workshops and the studies conducted, this type of content is sure to enhance DEDOS-Editor, DEDOS-Player and DEDOS-Web.

Regarding the integration of new technologies in the classroom, one of the main lines of work involves enhancing the acquisition of social skills such as communication, argumentation etc., apart from knowledge gain. Even if the studies carried out are insufficient to determine whether technology positively impacts students, the results obtained encourage us to continue performing more trials to check whether the results will be replicated in different institutions and educational levels.

As explained in the first chapter, although technology and society have undergone profound changes, the lecturing method has persisted throughout the years without much variation. This work has shown that many teachers use technology to support their own methodology when lecturing, without exploiting all the potential that such technology could offer. Once teachers adequately control the available technology and use it to support their teaching methods, they will learn and acquire digital competences that will enable them to evolve towards newer and more advanced technology in the future. In this way, it seems easier for teachers to continuously familiarise themselves with technology so that they can evolve slowly but surely, rather than trying to introduce a total digital revolution of the classroom. Therefore, pushing for teachers to first work in a small environment with technology, and creating technology that adapts to teachers' needs and

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pedagogies, could be crucial factors which will result in a change in education (Sollerval & Milrad, 2012).

10.4 Publications

In total, this thesis has led to the publication of two journal papers, six papers for international conferences, two papers for national conferences and a book chapter. Lastly, another paper was published for a national conference about work related to technology's enhancement of learning and labour integration. In the next subsections, full details about all these publications are included.

10.4.1 Journals

- Roldán-Álvarez, D., Martín, E., García-Herranz, M., & Haya, P. A. (2016) Mind the gap: Impact on learnability of user interface design of authoring tools for teachers. International Journal of Human-Computer Studies, 94, 18-34. DOI: http://dx.doi.org/10.1016/j.ijhcs.2016.04.011. **Q2 Impact factor: 1.476**

- Roldán-Álvarez, D., Martín, E., Haya, P. A., García-Herranz, M., Sánchez-Alonso, A., & Berdud, M. L. (2013) Proyecto DEDOS: Actividades educativas interactivas orientadas a superficies multicontacto. Revista digital de la asociación espiral, educación y tecnología. Núm. 1, ISSN 2339-6903, pp. 31-45. https://goo.gl/kYtD8y.

10.4.2 International conferences

- Roldán-Álvarez, D., Márquez-Fernández, A., Martín, E., & Guzmán, C. (2016) Learning Experiences Using Tablets with Children and People with Autism Spectrum Disorder. In European Conference on Technology Enhanced Learning, pp. 640-643. Springer International Publishing. DOI: http://dx.doi.org/10.1007/978-3-319-45153-4_81.

- Roldán-Álvarez, D., Martín, E., Martín, Ó. M., & Haya, P. A. (2016) DEDOS-Player: Educational Activities for Touch Devices. In European Conference on Technology Enhanced Learning, pp. 525-528. Springer International Publishing. DOI: http://dx.doi.org/10.1007/978-3-319-45153-4_55.

- Roldán-Álvarez, D., Gomez, J., Márquez-Fernández, A., Martín, E., & Montoro, G. (2016) Mobile Devices as Assistive Technologies for ASD: Experiences in the Classroom. In International Conference of Design, User Experience, and Usability,

pp. 187-197. Springer International Publishing. DOI: http://dx.doi.org/10.1007/978-3-319-40355-7_18.

- Roldán-Álvarez, D., Márquez-Fernández, A., Rosado-Martín, S., Martín, E., Haya, P. A., & García-Herranz, M. (2014) Benefits of combining multitouch tabletops and turn-based collaborative learning activities for people with cognitive disabilities and people with ASD. In 2014 IEEE 14th International Conference on Advanced Learning Technologies, pp. 566-570. IEEE. DOI: http://dx.doi.org/10.1109/ICALT.2014.166.

- Roldán, D., Martín, E., Haya, P. A., & García-Herranz del Olmo, M. (2011) Adaptive activities for inclusive learning using multitouch tabletops: an approach. In CEUR Workshop Proceedings. Diana Perez-Marin, Milos Kravcik, Olga C. Santos. Web: http://ceur-ws.org/Vol-732/paper10.pdf. Last access: January 2017.

- Martín, E., Haya, P. A., Roldán, D., & García-Herranz, M. (2011) Generating adaptive collaborative learning activities for multitouch tabletops. Computer Assisted Learning (CAL) Manchester, UK, 13-15.

10.4.3 National conferences

- Sánchez-Alonso, A., Martín, E., García-Herranz, M., Roldán-Álvarez, D., Berdud-Murillo, M.L., Haya, P.A. (2013) Proyecto DEDOS. Herramientas para el diseño y uso de actividades educativas en superficies multicontacto. In V Congreso Internacional de Diseño, Redes de Investigación y Tecnología para todos (DRT4ALL), pp. 35-39, Madrid (Spain). Web: https://goo.gl/MpBDdD. Last access: January 2017.

- Rosado, S., Roldán, D., Martín, E., Haya, P.A., García-Herranz, M., Sánchez, A., Berdud, M.L. (2013) Actividades Educativas en Mesas Multicontacto para Alumnos con Discapacidad Intelectual. XIV Congreso Internacional de Interacción Persona - Ordenador, dentro del CEDI, pp. 27-30. ISBN: 978-84-695-8352-4. Web: http://aipo.es/files/actas/ActasInteraccion2013.pdf. Last access: January 2017.

10.4.4 Book chapter

- Roldán-Álvarez D., Márquez-Fernández, A., Rosado S., Martín E., Haya P.A. (2016). Realización de actividades educativas en mesas multicontacto y actividades colaborativas para personas con discapacidad cognitiva y trastorno del espectro

autista. En: VI premio de investigación e innovación sobre personas con discapacidad intelectual, pp. 477-541. Manresa: Ampans Servei d'Impremta.

10.4.5 Related work

Apart from the previous results, and within the area of technology-enhanced learning, a study was carried out to evaluate the impact of video-based learning on students with intellectual disabilities. This experiment produced a national conference paper. This paper won the 'Antonio Vaquero' award for the best paper presented at the XVIII Simposio Inernacional de Informática Educativa (SIIE 2016), organised within the V Congreso Español de Informática (CEDI 2016) which was held in Salamanca (Spain).

- Roldán-Álvarez, D., de Miguel, S., & Martin, E. (2016) Combining traditional methodologies and social networks to teach job related skills to students with special needs. In Computers in Education (SIIE), 2016 International Symposium on (pp. 1-6). IEEE. DOI: https://doi.org/10.1109/SIIE.2016.7751821.

10.5 Awards

- Third prize, '**VII Premio de investigación e innovación sobre personas con discapacidad intelectual de AMPANS',** in the innovation category for the work '*Realización de Actividades educativas en mesas multicontacto y actividades colaborativas para personas con discapacidad cognitiva y trastorno del espectro autista'*. Given in Manresa (Barcelona, Spain). May 2016. Available at: https://goo.gl/cMAo6d. Last access: January 2017.

- **Premio al mejor Trabajo Fin de Máster** with the title '*Autoría y realización de actividades educativas en superficies multicontacto'* in the II edición de los premios fin de carrera de itSMF. Awarded in Madrid (Spain). May 2015. Available at: https://goo.gl/gGYxPA. January 2017.

- **Winner** of the award **mejor proyecto TIC en educación inclusiva, igualdad y diversidad** en **SIMO Educación 2014** by DEDOS project. Awarded in Madrid (Spain). October 2014.

- **Finalist** of the **mejor app educativa para docentes** en **SIMO Educación 2013** with DEDOS-Project. The other finalists were: Suite Educativa – Escudo Web (CRAMBO - ganador), Aumentaty (BINETEC, SL) y DEDOS (URJC, UAM y FSDM). Awarded in Madrid (Spain). October 2013.

- **Premio al mejor artículo corto** del congreso Interacción Persona-Ordenador titled '*Actividades Educativas en Mesas Multicontacto para Alumnos con Discapacidad Intelectual'*. Awarded in Madrid (Spain). Sepember 2013. Available at: http://www.aipo.es/interaccion2013. Last access: January 2017.

- **Premio eMadrid 2012** for the Master Degree Project '*Autoría y realización de actividades educativas en superficies multi-contacto'* done by David Roldán Álvarez, student of the Máster en Informática Interactiva y Multimedia. Awarded in Madrid (Spain). July 2012. Available at: https://goo.gl/mM2xT1. Last access: January 2017.

- Award '**Jóvenes Investigadores de la Universidad Rey Juan Carlos**' for the Master Degree Project in computer engineering for the work '*Autoría y realización de actividades educativas en superficies multicontacto*' done by David Roldan Alvarez. Awarded in Madrid (Spain). December 2011. Available at: https://goo.gl/nbCacj. Last access: January 2017.

10.6 Dissemination

There have been several dissemination activities related to the work carried out in this thesis. The complete list is as follows:

- Presentation of the experiment 'Realización de actividades educativas en tabletas digitales por estudiantes con necesidades especiales') in 'Jornadas de Innovación y TIC Educativas 2015'. 24 November 2015. Universidad Rey Juan Carlos. Móstoles, Madrid.

- DEDOS workshop in 'Jornadas de Innovación y TIC Educativas de la Universidad Rey Juan Carlos'. 27 November 2014. Universidad Rey Juan Carlos. Móstoles, Madrid. Link: https://goo.gl/YZjADW. Last access: February 2017.

- Presentation of the learning experiments carried out within Proyecto DEDOS in Jornadas de Tecnologías y Discapacidad. 14 November 2014. Universidad Rey Juan Carlos. Campus de Vicálvaro, Madrid. Link: http://clipit.es/ticdiscapacidad/. Last access: January 2017.

- DEDOS workshop in la Semana de la Ciencia de la Comunidad de Madrid 2014. 12 November 2014. Universidad Rey Juan Carlos. Campus de Móstoles, Madrid.

- DEDOS workshop in Noche de los Investigadores de la Universidad Rey Juan Carlos. 26 September 2014. Universidad Rey Juan Carlos. Campus de Fuenlabrada, Madrid.

- Presentation about the use of DEDOS by people with Autism Spectrum Disorder in Congreso Nacional de Educación Inclusiva Tecnología Aplicada, organised by INFOSAL. 29 May 2014. Universidad Rey Juan Carlos Campus de Vicálvaro. Link: https://goo.gl/IbDO3j. Last access: January 2017

- Presentation of educational projects designed with DEDOS (27 May 2014) in Centro Regional de Información y Formación 'las Acacias'. Link: https://goo.gl/CQlyLG. Last access: January 2017.

- Presentation of DEDOS Project to students of the Máster y Doctorado of Universidad Carlos III of Madrid. 17-18 March 2014. Universidad Carlos III. Leganés, Madrid.

- Upload of video tutorials to YouTube about the use of DEDOS-Editor (11 March 2014). https://goo.gl/EldwlJ. Last access: January 2017

- Inverycrea launches a contest about design of educational activities with DEDOS for current teachers. Duration: 17 March 2014 - 23 May 2014. https://goo.gl/vJUdNd. Last access: January 2017

- DEDOS workshop. 25 February 2014. Instituto de Psico-Pediatría Dr. Quintero Lumbreras. Madrid.

- DEDOS workshop. 11 February 2014. CPEE Fundación Goyeneche. Madrid.

- Presentation of DEDOS project (23 January 2014) at the Centro Regional de Innovación y Formación Las Acacias.

- Workshop 'Creación de actividades educativas colaborativas: Nuevas tecnologías educativas'. 26 September 2014. Noche de los Investigadores de la Universidad Rey Juan Carlos. More information at: https://goo.gl/0hDyq2. Last access: January 2017

- Workshop 'Creación de actividades educativas colaborativas: Nuevas tecnologías educativas'. 10 November 2013. Semana de la Ciencia de la Comunidad de Madrid 2013. Universidad Rey Juan Carlos. Campus de Móstoles, Madrid. https://goo.gl/sIyTl6. Last access: January 2017.

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