Authoring Tool for Creating Tangible Interaction-Based Educational Activities

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ABSTRACT

This paper presents the design of an authoring tool for creating educational activities based on tangible interaction. First, background information is presented in relation to tangible interaction and its possibilities for the educational context. Also, the concept of authoring tool is reviewed, and a number of desirable features for authoring tools oriented to the educational context are listed. Finally, TIES (Tangible Interaction in Educational Scenario) is described, which is the authoring tool we designed and upon which this paper is focused. The reasons why this is a necessary tool are discussed, and some conclusions and future lines of work are presented.

Keywords: Authoring Tool, Tangible Interaction, Educational Scenario.

1 INTRODUCTION

In 1993, Wellner, Mackay and Gold stated that "*for the most part, our computing takes place sitting in front of, and staring at, a single glowing screen attached to an array of buttons and a mouse. Our different tasks are assigned to homogeneous overlapping windows. From the isolation of our workstations we try to interact with our surrounding environment, but the two worlds have little in common*" [1].

Ishii and Ullmer [2] also stated that we live torn between our physical environment and cyberspace. They highlighted the division existing between the world of bits and the world of atoms, and the current need of human beings of having that sort of co--presence by being connected at all times. Based on these ideas, and taking into account Weiser's ideas [3] about ubiquitous computation, Ishii proposes taking advantage of the *affordance* of the objects in our environment to achieve a better interaction between people and information technologies. In his

"*Tangible Bits*" article, he describes his proposal on how to narrow the gap between the physical environment and cyberspace [2]. This is the origin of the concept of tangible interaction (TI), in which, through the physical manipulation of tangible representations (objects in the environment), digital representations are altered. Physical shapes, then, can be used both for representing and controlling their digitales counterparts. Currently, the concept of tangible interfaces supported by the physical environment, using objects, surfaces and spaces that embody digital information [4] is being discussed.

There is a wide range of applications that are based on tangible interaction, both for the educational context and for entertainment. However, each of these applications is designed on an ad-hoc basis for each specific need. There are now a few works that present *toolkits* to help developers bypass the lower-level tiers involved in TI applications and focus on higher-level tiers [5][27][28]. This is important because TI-based applications involve object detection, be this through the use of markers, by processing the image of an object, or through RFDI (*Radio Frequency Identification*), and they oftentimes require libraries for capturing and identifying images of interest in the physical environment being used. At the same time, these libraries must "talk" to the libraries or modules owned by the application being developed. In the case of the design of educational activities based on tangible interaction, educator participation in activity creation is required [6]. It is inconceivable that educators should face the task of developing these educational activities without appropriate authoring tools. In this article, we present the first steps towards the design of a template-based authoring tool that allows educators setting up their own tangible interaction-based activities. Thus, an abstraction tier is provided that is transparent for educators in relation to lower-level TI aspects. This authoring tool is considered to be a contribution for the growth of TI-related possibilities in the educational context.

The article is organized in the following sections: in Section 2, background that connects TI to the educational context is reviewed, and some works that propose *toolkits* for the development of TI applications are described; Section 3 introduces the concept of authoring tool and describes the aspects that are desirable in authoring tools that are aimed at the educational context; Section 4 presents our contribution, which is TIES, an authoring tool oriented to the creation of TI-based educational activities; in Section 5, the technical aspects related to the development of TIES are discussed; in Section 6, some considerations that have contributed to the creation of the authoring tool are explained; and finally, Section 7 outlines the first conclusions drawn in relation to TIES and presents future lines of work.

2 BACKGROUND

Tangible interaction-based systems have entered the radar of researchers in different disciplines such as cognitive psychology, education and educational technology. There is a general belief in relation to the manipulation of physical objects and their link to learning and development in people [7]. For example, Montessori [8] believed that, by playing with physical objects, children were able to get involved in activities that had a specific purpose, and therefore considered such physical objects as developmental tools. Dienes blocks [9] are another example, where physical objects are manipulated to teach abstract concepts, such as variable and value. O'Malley and Fraser [7] present an interesting review of the possibilities offered by tangible interaction in the educational context, and they present a detailed analysis of the connections between physical representations and virtual representations. In their conclusions, they explain that the importance of physical and multisensorial activities is being increasingly acknowledged, especially during the first years of development of an individual. However, they also observe that these activities are being carried out without using Information and Communication Technologies (ICTs), and that the use of activities that combine interaction with physical and digital objects would be desirable.

Marshall et al. [10] state that the tangible approach is becoming an alternative for traditional graphic user interfaces. These authors consider two types of reflexive learning stemming from the work carried out with tangible interfaces. First, the student can learn to use tangible manipulations for some task. In this case, learning is highly situated, i.e., it proposes how to use a certain tool in a specific context. Secondly, the TI system can encapsulate some theoretical model of the world. In this situation, students can explore the model through interaction with tangible manipulations. Thus, according to Marshall et al. [10], there are two types of activities that can be carried out using tangible manipulations: 1) an expressive activity, where the tangible aspects somehow embody the behavior of the student (either physically or digitally), and 2) an exploratory activity, where the tangible aspects embody a model that is given to the student to explore and analyze and that has been planned by some designer. Students explore this model and confront it with their own mental models.

On the other hand, the use of active surfaces, such as *tabletops,* strengthens some possibilities for the integration of activities based on tangible interaction in the educational context [11] [12] [13]. In particular, work by [14] [15] highlight the possibilities of tangible applications based on tabletops for the development of face-to-face, collaborative educational experiences.

The development of applications based on tangible interaction has been part, for years already, of the research and education scene, and this has been increasing recently. Some of these applications are designed as a companion for the storytelling process [4], others are aimed at teaching programming [16] [17] [18], or aimed at planning and logistics [19], or teaching art-related topics [20], or aimed at the scenario of special education and communication [21], to mention but a few.

However, in all of these, application creation is not trivial and is usually done on an ad-hoc basis. Therefore, there is a need to produce tools that facilitate the task and enable educators who participate in the design of TI-based activities, so that they can specify their goals, feedback, images, and activity sequence, for instance.

Some articles that propose adding tiers to provide different abstraction levels for the development stage of a tangible application have been reviewed. This tiered model would make lower level implementation more transparent in relation, for instance, to the detection of the physical objects used in the real environment to interact with the virtual one [22]. Such is the case of *ToyVision,* which proposes a layered architecture and is aimed at facilitating the development of board games. *ToyVision* offers possibilities for modeling the type of physical object that will be used with the application, as well as the way in which it will be recognized [5]. Taking these studies as a starting point, together with experiences carried out with TI activities for the educational context [6], the importance of implementing authoring tools that are focused on the creation of educational activities based on TI is considered. This article is developed along that line.

In the following section, the concept of authoring tool is discussed, and then TIES is introduced, which is an authoring tool that was especially designed for creating educational activities that are based on TI.

3 AUTHORING TOOLS FOR THE EDUCATIONAL CONTEXT. DESIRABLE ASPECTS

Authoring tools are programs that allow users to create their own multimedia objects without the help of a computer specialist. These tools were developed with the idea that all individuals could have a way to express their ideas in digital format. Therefore, they usually consist of software with user-friendly interfaces, a large number of help tips, and a selection of predefined templates to help users who are not familiar with programming. Working with authoring tools that are oriented to the educational context can enrich teaching proposals as well as expand the possibilities for student expression and communication [23].

Gómez Villa et al. [24] state that "*authoring tools are those that allow, through a more or less complex compiling process, generating a program that runs independently from the software that was used to generate it,*" and, in a more specific sense, this group includes "all those tools that allow generating multimedia activities, materials and resources".

The article "Comparative Analysis of Authoring Tools for Creating Augmented Reality Activities" [25], describes the authoring tools that are aimed at the educational context, taking into account a number of common features in relation to pedagogical, technological, and visual design aspects, such as:

- Building various types of didactic activities from specifically designed templates with the purpose of achieving different educational goals.
- Including the possibility of adding statements and goals for the activities to be designed.
- Setting up a feedback channel for students, which can be in text, sound, and/or visual format. This will allow students get more information about their performance in a given activity, and learn from their solution.
- Building activity sequences based on pedagogical objectives.
- Offering different possibilities for navigating activities.
- Customizing the presentation and visual design aspects of the activities that are being created.

Based on these observations, an authoring tool called TIES was designed. This tool can be used to create educational activities that are based on tangible interaction taking into account the features that are common to the authoring tools that are oriented to the educational context. The design of this tool is a realization from previous works of the authors in the area of TI and the review of authoring tools for the educational context.

4 TIES: *TANGIBLE INTERACTION IN EDUCATIONAL SCENARIO*

This section presents the development of the first version of an authoring tool that allows creating educational activities based on tangible interaction. Additionally, this tool has a component that allows playing the activities generated by the authoring tool mentioned above. Therefore, a distinction will be made between these two components of TIES – *TIESViewer* and *TIESAuthor* (see Fig. 1). *TIESViewer* is a module that allows students/recipients to carry out a TI project configured with *TIESAuthor* and run on a tabletop. In this paper, we focus on the *TIESAuthor* component, which is described below; although reference will be made to some aspects of *TIESViewer* to help the reader better understand the tool.
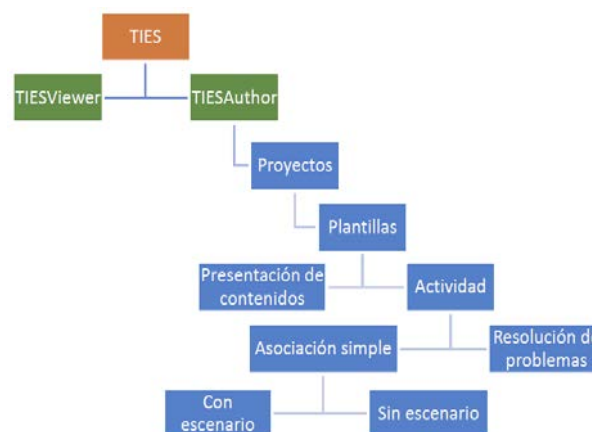

Fig. 1. TIES architecture

TIESAuthor

This module is a Web application that allows creating TI projects that are aimed at the educational context, to be then played with the viewer, *TIESViewer*. *TIESAuthor* has two levels for carrying out work: the level of the TI project, that allows packing the activities to order them into a sequence, and the level used for creating the activities based on specific templates (see Fig. 1).

- **TI Project Level**

The activities created using the *TIESAuthor* module can be packed into a TI project. When creating a project, the educator must input the following:

- General data: project name and topic, name and e-mail address of the author, and labels

for classifying the project (these will be used for searches).

- Contents and activities: the contents and activities that are included in the project must be added.
- Type of project: this defines the nature of the project – competitive, collaborative or individual activities. Mixed-type projects can also be set up. This choice will limit the type of activities that can be included and the way in which they will be displayed on the tabletop.
- Activity sequence: this defines the order in which activities will be presented, which in turn determines the navigation sequence for the user. This is used by *TIESViewer* to display the activities in a given order.
- Project feedback: choice between a summary of the score obtained in each of the activities and/or qualitative feedback set up by the educator. Thus, when a student completes all the activities using *TIESViewer,* the corresponding feedback is displayed and, if set up, the educator receives the summary by e-mail.

TIESAuthor offers two types of contents that correspond to different types of templates in the tool – information presentation template and activity template.

The information presentation template allows including an introduction or conclusion to each activity, listing instructions, etc. Videos, images, sound and text can be added. To present the information, a title must be introduced, followed by the information itself; to enter this information, a rich text editor is used. Also, an audio file can be attached to be played while the text with images is read. This template requires the educator either to define the duration of the presentation before moving on to the next component in the package, or to add an action component for the user to select when to continue with the next step.

- **Activities Level**

Activities are built from previously designed templates. So far, two types of templates have been created – problem solving template and simple association template (with or without scenario). Each activity template allows introducing its objective and purpose and, in the case of association activities, student feedback can also be set up. Feedback is categorized as "Fail", "Success" or "Closure". That is, the educator can define a specific feedback for each of these three categories.

Problem-Solving Activities

The problem solving template is available only for collaborative projects. This allows educators to generate activities in which students can work collaboratively to solve a problem.

The purpose of this type of activity is for a group of students to arrive at the solution for a problem that poses a number of questions. These questions must be answered by selecting a specific tangible object among those available for the activity.

Initially, each student receives information in the way of clues obtained by interacting with tangible objects and the tabletop. Then, a discussion and analysis stage is carried out in relation to the information received. The activity ends when participants arrive at a conclusion to solve the problem. The group wins if the conclusion matches the actual solution, and is assigned a score based on performance. If the conclusion is not correct, they can either try again or see the solution.

The problem solution activity is divided in stages, each of them with their own purpose and duration:

- **First stage:** a set of tangible objects is distributed among the participants. Through the object they each received, participants have access to unique information in relation to the problem to be solved. This information is referred to as problem clues. For example, an object is placed on the tabletop and information about the problem to be solved is displayed. Thus, the knowledge each player has, and therefore his/her contribution to group work, is essential for solving the problem (see Fig. 2).
- **Second stage:** players gather around the tabletop to share the clues that each of them received and analyzed, and they discuss possible solutions to the problem (collaborative stage per se). During this stage, the group can request additional information through additional clues (additional tangible objects) or by querying possible links between the clues they have already received (this is done by placing different objects on the tabletop) (see Fig. 3).
- **Third stage:** the group presents their conclusion by answering the questions proposed in the problem. The score obtained is displayed, and participants reflect on their performance and the overall result of the activity. Performance is affected by the time taken to finish each stage and the amount of additional information requested.

To create this type of activities, the educator configures the following aspects:
1. **General parameters:**
   a. Stage duration: for each stage, a duration value is defined.

b. Maximum amount of information to be recalled by each participant: possibility of selecting phrases about the information provided by a given object by placing the object on the tabletop.

c. Maximum number of additional clues tat can be requested: number of additional objects that can be requested by the group to obtain additional information about the problem by placing interacting with the tabletop.

d. Maximum number of links to be established: number of times that two objects can be linked, by placing them on the tabletop, to obtain information about possible relations between them.

e. Decision on whether to allow showing the solution to the problem or not and. If allowed, the image with the solution must be defined.

f. Decision on whether to allow multiple attempts to answer questions or not.

2. **Presentation of the case:** a video with the problem to be solved can be added.

3. **Number of participants:** this defines the number of participants. For each participant, the corresponding interaction objects must be specified. Also, for each object, the information that will be displayed on the tabletop is defined: title, text, image (optional), and possible phrases to be recalled – the phrases that participants will be able to recall (select) are entered (see Fig. 2).

4. **Additional clues:** for each additional clue, represented through a tangible object, the information (text and/or image) that will be displayed when the object id placed on the tabletop is specified (see Fig. 3).

5. **Relations between objects:** For each relation, the following is defined (see Fig. 3):

a. Identification of the two objects that are related – two of the objects that have already been loaded must be selected.

b. Information (text and/or image) that is displayed when the objects to be linked are placed on the tabletop.

6. **Questions to be solved:** For each question, the following is detailed (see Fig. 4):

a. Text of the question: the question to be solved.

b. Object that answers the question: the educator must choose which of the previously loaded objects answers this particular question.
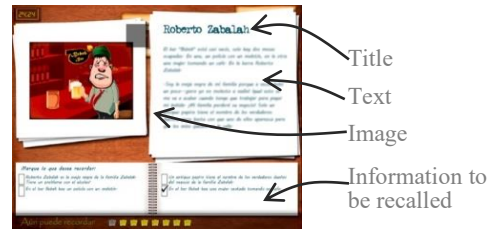
Thus, the educator configures the problem solving activity in TIES, considering purpose, feedback, and possibilities for each stage.

Fig. 2. Interaction object displayed on TIESViewer

Fig. 3. Additional information displayed on TIESViewer. The image on the left shows interaction with an additional clue. The image on the right shows the interaction with two objects when looking for a relation between them. On the upper part of each image, the gray boxes indicate the position where the objects have been placed. In both cases, image and text can be seen, which were previously configured by the educator in *TIESAuthor.*

Fig. 4. Questions displayed in TIESViewer

Simple Association Activities

Simple association activities can be included in either collaborative or individual projects, and they allow students to associate tangible objects to graphic representations or images on the plane.

There are two types of associations:

- **Simple without a scenario**

The graphic or image to associate is displayed on the surface of the tabletop, over a colored background, without showing the relation of that image to a specific scenario or context (see Fig. 5). To create a new simple association activity, the educator must specify the following:

- Name of the activity.

- Background color.

- Purpose.

- Tasks. Tasks correspond to the associations to be established by participants. For each task, the educator can define:
  a. An image.
  b. Size and position.
  c. Name: The name will be used to link the tangible object to the graphic.
  d. Task feedback. A sound and/or image can be selected, one for the correct answer and a different one in case of a wrong answer. Also, an image could be used to indicate neutral if no answer is provided.
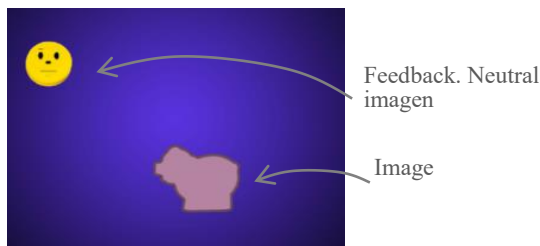

Fig. 5. Simple association activity displayed on TIESViewer

- **Simple with a scenario**

In this type of activities, tangible object associations to 2D representations are linked to a scenario. For this type of activities, the educator completes all configuration tasks as in the simple association activities with no scenario, but must also set a background image to represent a scenario that makes sense for the association tasks being proposed. Figure 6 shows an example of this type of activities (using *TIESViewer*, where the student must place in a shopping cart, corresponding to a supermarket scenario, those tangible objects that are related to the images of products displayed on the tabletop. In Figure 7, the person must place the real object tomato on the image of the shopping cart. These objects must carry a flag that allows the application to identify them. *TIESAuthor* offers the possibility of printing the flags that identify each object involved in the activity.

Fig. 6. Simple association activity with scenario displayed on TIESViewer

Fig. 7. Example of simple association application with scenario.

5 TECHNICAL ASPECTS

TIESViewer was developed in *Adobe Flash Builder 4.5*[1] and *ActionScript 3.0*[2] *(AS3)* running on *Adobe AIR*[3]. The choice of *Adobe AIR* was based on the security restrictions enforced by *Adobe Player,* which made local file storage impossible. *Adobe AIR* is a versatile run environment that allows creating desktop (general purpose) applications based on Web page development technologies, such as *HTML, Ajax,* or *Flash*. *TIESAuthor* was developed in *PHP* language, using *Laravel*, version 4.2. The design of the tool was based on *Framework Bootstrap v3.3.2*.

6 A FEW CONSIDERATIONS

The authors have been working on this topic for several years, especially on the development of different TI applications, on a tabletop, oriented to the educational context. One of these applications is AcoTI (*Augmentative Communication through Tangible Interaction*), which is an educational tool aimed at helping develop communication abilities in Complex Communication Needs (CCN) students,

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[1] Adobe® Flash® Builder™ is an integrated development environment (IDE) for building multi-platform rich Internet applications (RIAs). It is built on Eclipse and offers all the necessary tools to develop applications that use the Flex open code and ActionScript 3.0.
Flash Builder is run on Microsoft Windows and Apple Mac OS X, and several versions are available. http://www.adobe.com/

[2] ActionScript is the programming language for Adobe®Flash® Player and Adobe®AIR™ runtime environments. Among many other things, it activates interactivity and data management in Flash, Flex and AIR content and applications. It is run through ActionScript's virtual machine, which is part of Flash Player and AIR. ActionScript code is usually transformed into byte code format using a compiler. Compilers include the in-built compiler in Adobe® Flash® Builder™. The bytes code is in-built in the SWF files executed by Flash Player and AIR. Obtained from http://help.adobe.com

[3] Adobe AIR is multi-platform and free. http://www.adobe.com/

who typically are the users of Augmentative and Alternative Communication (AAC). It should be noted that field work has been carried out with students in Spain and educators and professional working in educational institutions in Argentina and Spain [6] [21]. These experiences were undoubtedly relevant for the development presented in this article. Assessments were key when considering the following aspects in the design of TIES:

1. Possibility of configuring the images/graphics to be associated to the tangible objects in an activity.
2. Possibility of configuring different types of feedback for activities (fail, success, neutral), and that these can be visual and/or audible.
3. Possibility, in the case of association activities with a scenario, of establishing a background image to represent the specific scenario.
4. Different ways for presenting instructions (audio, video, image and/or text).
5. Configurable chaining or sequencing of activities
6. Activities carried out individually, collaboratively and/or competitively as a game.

TIES is considered to have taken into account several decisions and ideas from end users (educators and students) for whom this authoring tool has been designed. This user feedback was collected through tests carried out with applications developed by the authors, which helped define configuration and design needs, as the case may be. At the same time, these tests confirmed the need for a tool for designing TI activities.

However, use tests for the tool should be carried out with these users to analyze usability aspects; this will be the focus of future publications.

7 CONCLUSIONS AND FUTURE WORK

TI-based applications are an alternative to current graphic user interfaces. Several authors have been reviewed who consider that tangible interaction represents an opportunity for the educational context, in particular, for the development of face-to-face collaborative activities, supported on tabletop-like interactive surfaces. Additionally, in certain contexts and educational designs, the use of physical objects from the environment represents an opportunity for learning.

TI-based educational activities require different design and development layers, going from high-level aspects that are more related to the context where the application is used (in this case, the educational context) and, therefore, involve instructional design, to lower-level aspects that are related to the detection of physical objects and their mapping to virtual objects.

TIES allows creating educational activities for all educational levels, its specific contribution to the area being the creation of TI-based educational activities, helping educators take part in their design and implementation. The main result achieved by this tool will likely be that of opening the road to a stronger link between tangible interaction and the educational context.

As future lines of work, we are planning to carry out usability tests for TIES, and integrate it with *AuthorAR*, which is an authoring tool for the creation of augmented reality educational activities [26].

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