Developing Downloadable TUIs for Online Pedagogic Activities

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Abstract

The Web has changed how we interact with the World's information and knowledge. As a result there have been several changes to the education sector, especially in online distance learning. Nevertheless, most of the e-Learning activities struggle to break the GUI paradigm. The HCI community has focused on the use of Tangible User Interfaces (TUI) for pedagogic purposes thus producing some evidence of the potential that embodied cognition might bring to constructivist learning. New education movements such as the Edupunk movement argue for an empowerment of independent learners, following the constructivist perspective where learners have to have a more active role by experimenting and discovering concepts on their own. However, we think that accessing TUI systems via Web can lead to pedagogic activities that break the GUI paradigm in education on the Web.

This paper presents a case study: three prototypes of TUIs for online learning and exploration were developed and tested, investigating the usability and engagement provided by this kind of interactive tools.

Author Keywords

Tangible User Interfaces; Engagement; Downloadable Interfaces; Constructivist Learning.

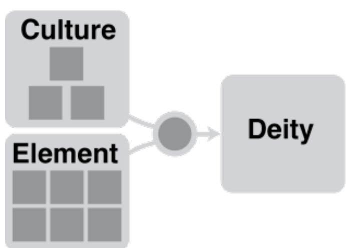

Figure 1. Relating elements and cultures.

Figure 2. Bases for the interfaces

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

The Web has changed in many ways how we interact with the world's information and it has promoted several new pedagogic approaches. Independently of the access potential or pedagogic innovation, it can be argued that on the Web, all learning activities have to be carried out through some sort of interface. From a wide variety of interaction paradigms, it can be said that TUIs provide a more powerful environment for pedagogic interaction. TUIs may ultimately have the potential to attract a wider spectrum of users [1] thus providing digital inclusion by using everyday, non-digital objects that allow users to perform computational transactions [2]. Added to this, TUIs can help offload mental effort when using an interactive system [2] letting users focus on the activity instead of the system itself.

From an educational perspective, it has been previously proposed that learning is an active process where the construction of meaning can be produced through activities that engage both mind and body [3]. Added to this, Constructivism calls for an active involvement of the learner where he or she is required to interact with the world and manipulate it to be able to reach their own conclusions [4]. The Edupunk movement emphasise that the learner must be an owner and producer of their own knowledge [5, 6]. Through this approach, learners are capable of building their conclusions whilst learning and building the tools for engaging in the educational activity. Based on this and seizing the benefits from TUIs, we propose that a user should be able to download and build his/her own TUI learning activity in an online learning environment.

Previous research on downloadable TUIs by Costanza et al. [7] has made evident that their use may be one of the ways forward to distribute TUIs in several disciplines. This is an area that still requires further work. Nonetheless, allowing users to build their own learning environment can have particular benefits, since learning in a familiar environment has been proven to enhance the learning abilities of users [8]. Another important factor is the ease of accessing materials to build these tools. To address this issue in the particular case of our example, the interfaces developed use only off-the-shelf consumer electronics. The interfaces presented in this paper were designed in such a way that they can be downloaded and built at home.

Having a museum related pedagogic activity in mind in this paper we introduce three TUIs. The user can explore combinations of designs depicting diverse ancient cultures and natural elements to retrieve information about a 'deity' relevant to such cultures as a result. The cultures chosen for this example were Aztec, Greek, and Egyptian. Three methods of interaction were used: dice, tokens and disc.

Design Approach

Our research followed Gottlieb's model [9], conceiving the development of a pedagogic design element embodying an activity as part of a constructivist system. This is to say that the system must allow the user to (1) learn at his/her own pace and through an active process and (2) build the tools allowing them to appropriate the system and encourage engagement. It

Figure 3. Dice version.

Figure 4. Token version.

Figure 5. Disc version.

was also important to produce a system that was capable of very simple communication since an appropriate visual communication system can enhance didactic material [10]. We aimed the design of the deity to be visually appealing to the users inviting them to interact beyond the activity (i.e. printing the character as a paper toy). It was thought that the characterization of the deity should help produce empathy with them, thereby encouraging the user to explore the system further [11, 12]. However, Costanza et al. [7] mentioned how in reality, there has been no significant advance in understanding about the impact the aesthetic quality of such interfaces can produce.

The Interfaces

The topic chosen for the interfaces was 'gods and cultures'. Concepts such as 'fire', 'water', 'earth' and 'wind' and their related deities, seem to be comparable in many different cultures. Three different types of TUI illustrated the same topic (gods and cultures), including the same concepts and elements. Our aim was to identify how users interact with different tangible objects, especially when working with abstract concepts. The exploration was based on linking the culture and an element that represents a deity (Figure 1). The interfaces explored three cultures: Aztec, Egyptian and Greek, and six elements were represented: fire, wind, water, music, death, and king of gods or god of gods. When combining a culture (e.g. Greek) and an element (e.g. water), the system displays a visual representation of the deity and some basic information about it. All three interfaces were presented with an interaction 'base' that served as an area delimiter for the webcam video range that captured the fiducial markers (Figures 2, 4 and 5). The design elements were made to fit on an A4 paper size, thus it can be scaled to any size thus encouraging appropriation.

Dice Interface

In this interface two dice were used to interact with the proposed concepts. One die encompassed the cultures while the second represented the natural elements allowing the user to separate the concepts or to work with them at the same time (Figure 3). When the user placed both dice on the interactive area, the interface then displayed through a projector the god representing the selected combination in the prepared paper shape (Figure 8). Their construction in paper was thought as important due to the accessibility of the material and the flexibility in terms of shapes that can provide. Paper-based materials offer an advantage in accessibility as the system can be easily printed and built at home.

Token Interface

In this version the representations of the natural elements were distributed on tokens. The interface provided a single double-sided token per element. The cultures were represented on a map in grey and a green circle indicated the 'interactive area' (Figure 4). This interface also calculated the position of the token in relation to the interactive area. The interactive area had four markers that were detected by a computer vision system (***d-touch)*** that helped establish the relative position of the marker and sent it to Adobe Flash (as explained in the next section). The interactive area was divided into three columns, one for each culture identifiable by the graphic of the present country of origin. This was the only experiment that implemented spatial mapping. The user was able to place the token in any section of the interactive area, but by drawing the green circles, their purpose was to attract their activities to that section since they were visually connected to the country where the selected culture originated from.

Disc Interface

The disc version integrated both the culture and the natural element into a single tangible interface. The interface used two discs built within it: one for the cultures and another for the elements. Each disc had a handle that allowed the user to spin the discs. The interface was built in such a way that a window allowed users to see only one marker from each disc (Figure 5). When the user rotated the disc and the desired markers were visible, the resultant information was displayed (Figure 8).

Figure 6. Elements and cultures.

Implementation.

The system works by identifying visual markers through a webcam. The webcam was connected to a visual marker recognition system called ***d-touch*** [13] that recognised the topology of the marker [14]. Once the marker is recognized, an identifier is assigned to it. The identifier can contain properties such as ID, angle, x and y position, and scale. This information can be retrieved through a "*standard socket based client*" that also allows other applications to retrieve and use their information [14]. The 'socket' was connected to Adobe Flash, where all the interactivity was created (Figure 7).

The deities resulting from the combinations tried by the user were projected onto a solid object that served as a template (Figure 8). This visual output was produced from a consumer notebook computer that contained the Flash application connected to d-touch. While the design included the possibility of printing the gods and assembling them as toys, in the case of the experiment carried out in the laboratory this step was not implemented. The interface could just display information on a screen, but instead it was decided to use a projector in order to reproduce the effect of the 'physical result' planned through the design of the printed toys. The interfaces have been designed to produce an identical output which is the one projected on the substrate. The setup of the projector has to be done only once by matching the light to the projection substrates. A mini projector (Pico Projector) was also used, which has the advantage of being very affordable. The main reason for using this projector instead of a full size one was that due to its size is less intrusive in relation of the other components of the interface.

The interfaces were designed in a way that setting up requires basic computer skills such as running an application and installing a webcam. Certainly, adding a projector complicates the setup. This can be addressed by providing pre-assembled kits or different output versions for different user requirements. The setup of the interface will require adult supervision due to the nature of the activity that requires using glue and scissors or a scalpel. The physical objects were designed using basic geometric shapes so their construction requires only basic skills.

Comparative study

Even though the design was aimed to be used by a wide variety of age groups, especially by children, the pilot study was performed only on adults. The evaluation was carried out with a sample of 24 adults from different digital skill levels. The interfaces were

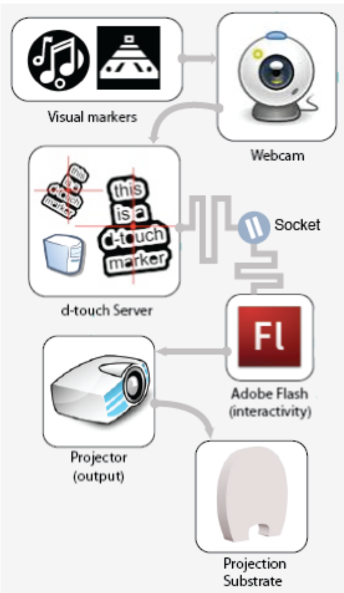

Figure 7. System's technology

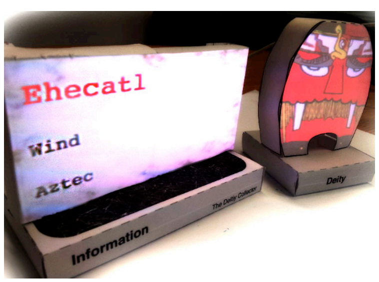

Figure 8. Deity and information projected on substrate.

tested in a randomized sequence. For each interface, the user was asked to find a specific combination of 'element' and 'culture'. This was performed three times per interface. Participant's completion time was measured for each of the tasks. After performing the tasks, participants were offered the chance to play and explore freely the interface if desired. The time they spend on free-play was also measured. Participants answered a survey based on a System Usability Scale (SUS), combined with an exit usability questionnaire. After calculating the SUS test on the interfaces, a non-parametric Kruskal Wallis one-way-analysis of variance-by-ranks test was performed to test if there was a significant difference between the interfaces.

Results

In terms of time task completion the dice and disk performed equally well, while the performance of task time completion for the disk differs significantly from the other two interfaces. In terms of "extra play time" there was no statistically significant difference. This means that people played with the three interfaces for a similar amount of time. The Token and Dice presented a significant difference in their score against the Disc system. The Token and Dice presented a high score in the SUS. Task completion time was related to their usability score. This seems to show that a good usability level improves the user's performance, therefore reducing their completion time in the test.

The disc was the interface with the lowest usability score. However, many participants indicated that this interface presented a sense of serendipity that appealed more for exploration than for performing defined tasks. Although during the design phase the use of the spinning disc was assumed an activity that children would find appealing, some mechanical problems in it seem to have made it appear to be as an activity for older people due to its mechanical complexity. Evidently, the Token interface presented the most positive results and feedback. Many participants liked the amount of information presented, combined with the ease of use, and 50% of participants identified this system as a system that would appeal to everybody, while a 33% pinned it as an activity just for children. While 13% of participants thought it was designed for older children, just 4% saw it as an activity solely for adults.

Conclusions

There seem to be several advantages in the adoption of these types of systems, where from an interactive perspective, the users can offload mental processes as part of a TUI system, and through a didactic activity they can 'create' by building their own tools, generating in this way a sense of ownership.

The system developed has the advantage that it can be applied in a wide variety of topics, but its main potential lies in the promotion of a constructivist distance-learning environment. Appropriation of knowledge is important, and in this case, the interface users can 'own' what they created through the printed production of their god characters, which enhances the learning experience. In addition, the mental offloading that tangibility facilitates, may allow a more complex system of exploration/combination to be implemented, which will be researched in the future.

This research focused on the ways information can be explored via TUIs as independent learners and provides meaningful results as a first approach to the topic, pointing out what users were looking for when presented with these types of interfaces. The learning curve in the learning process of participants seems to have been short while engaging with the information provided. This could prove to be beneficial in different groups (e.g. children, elderly) and in the engagement with different sets of information. Although more research is needed, it may be possible to test that by transforming abstract concepts into graspable items, the system could alleviate mental processes, allowing the user to focus on the information presented.

Acknowledgments

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