M-Dimensions: a Framework for Evaluating and Comparing Interactive Installations in Museums

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ABSTRACT
Designing and evaluating digital interactive experiences for museums requires scrupulous attention to every aspect that contributes to an engaging and rich learning experience. The evaluation of interactive installations in museums is a very demanding endeavor due to the intersection of multiple research fields, such as human computer interaction, design and multimedia, museum studies, audience research, etc.

In this paper we introduce a novel framework with ten dimensions for guiding the design and evaluation of interactive installations, specifically tailored to museums. The conception of the framework was based on current usability evaluation methods and principles as well as museology literature. It was then iteratively refined and finally validated with and a long-term study about interactivity in all the interactive museums of a specific geographic region.

The results obtained emphasize the importance of adopting the proposed framework for future research on interactive museums evaluation.

Keywords
Evaluation methods, framework, interactive installations, museums, interaction design.

ACM Classification Keywords
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies*.

INTRODUCTION

Designing interactive installations for museums has become increasingly popular 12 since museums are more open to exploring the possibilities brought by the digital realms in order to attract younger and wider audiences. However, the recent advances in novel interaction paradigms have rendered such flexibility to the available technology that interaction designers are faced with a very large solution space. This makes it more strenuous to take the right design decisions, aggravated by the complexity of the museum as an application domain *per se*. Creating an engaging and rich learning experience in a museum context can then become an excruciating experience, especially for novice interaction designers or designers who do not frequently deal with museums as an application domain. This leads to the need for practical principles aiding the design and evaluation of interactive experiences in museums.

In this context, our contribution is a new framework that can be used for tackling this problem: guiding the design and evaluation of such interactive installations. The conception of the framework was based on (i) current usability evaluation methods and principles, in particular Constantine's design principles 5, (ii) museology literature, (iii) iterations with teams of interaction design experts focused on museum interactive installations, and (iv) a long-term study about interactivity in seven different museums.

Although the framework is useful for evaluating and comparing the quality of the interactive installations in the museums, it can also be used to anticipate and avoid in the first place many of the interaction design mistakes that are otherwise overlooked until usability tests *in loco* are performed with real museum visitors.

Motivation

Interactive museums are becoming popular due to several factors [10, 18]. On one hand, this type of installation enhances learning by exploration or discovery of the visitors themselves. They have an active role in the acquisition of new knowledge through a new and engaging experience totally different from formal learning environments such as classrooms. On the other hand, interactive museums are also a new way of entertaining activity for visitors at the same time that encourages the modernization and visibility museums.

Many long, detailed frameworks providing design principles and interaction design heuristics have been compiled

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and written by different authors. The most widely touted list of heuristics is Nielsen's ten design heuristics [20, 21], which became the industry's *de facto* framework of reference regarding everything related to usability evaluation.

Evaluating the interactivity level of the interactive installations of a given museum is an activity that requires a standard evaluation framework, in order to create a pattern to be applied in every museum, so that they can be compared. For museums, this pattern does not yet exist and that is the main reason for creating our proposed framework, which is targeted at museum interactivity evaluation. Between other relevant aspects, it allows not only to gain insight about the interactivity level of the installations in each museum, but also to compare different museums, identifying their strengths and weaknesses as well as concrete areas for future improvements. Additionally, it acts as a set of practical design principles that designers can keep in mind when focusing on developing museum interactive installations.

Our evaluation framework was built on top of solid components, like the Constantine and Lockwood's principles of good form 5, Nielsen's popular heuristic evaluation framework 21 as well as other relevant elements for the museum context such as the degree of the interactive installations integration in museum exhibitions 23, learning and education [16, 26], entertainment 25 and collaboration [2, 23].

Defining Interactivity in Museums

Nowadays, the concept of interaction is widely used in many different areas and therefore has several meanings associated with. In general, *interaction* can be defined as the exchange of information between two or more active participants 22. However, and for the sake of clarity, we are interested in defining the notion of interactivity in the museum context. In this paper, we consider interactivity as the visitor's ability to provide instructions to the interactive installation through actions taken on the installation itself or its objects. In other words, interactivity in a museum can be described as the visitor's ability to change the content and control the information he receives through gestures or actions [3, 12].

Interactivity in museums can employ or not employ digital technology or Information Technology (IT) solutions. This means that two main types of interactive installations can be considered: those that use technology – *digital installations* (gesture-based or multitouch interactive tables, floors, kiosks, etc.) [3, 23], and those that do not. Throughout this paper we will designate those installations as *non-digital* installations (drawers, doors, knobs, books, etc.) [10, 23].

The remaining of this paper is organized in the following way: the first section describes the relation between our framework and existing evaluation approaches. Secondly, we describe the M-Dimensions framework, a novel systematic and well-grounded approach to evaluate interactive installations in a museum context. Thereafter, is described and explained the iterative process of defining the framework's dimensions and usable ways to make it more appealing, both to designers and evaluators. Next, we describe the limitations and advantages of the framework, and also the application of M-Dimensions in a concrete way. Last, we present our results, outline conclusions and future work directions.

RELATED WORK

Heuristic evaluation 21 is a very popular technique that has been successfully applied to many different application domains throughout the years. These domains range from health technologies 17, history educational games 26, child e-learning applications 1, e-Government websites 9and even go as far as security management tools 23, among many others.

Despite these advances in heuristic evaluation frameworks, the evaluation of interactive installations in museums is a very challenging and difficult task because of the intersection of multiple research fields. Although heuristic evaluation has become a widely accepted method of usability evaluation in software development, it is necessary to include other important parameters from the different research fields involved in museum interactive technologies.

With the increasing application of interactive technologies in museums [24, 25] conventional human-computer interaction evaluation methods, for instance heuristic evaluation 21 have been applied to evaluate the interactive installations within the museum context. However these methods may depend on the person who is performing the evaluation, usually the installation designers [18, 21]. On the other hand, in the museum field, the evaluation of interactive installations typically includes observation techniques, user questionnaires and comments or interviews [12, 18]. Usually, general opinions are obtained by using these techniques and some lessons for future installations are highlighted. Moreover, this information can also be used to verify if an installation is interactive or not, whether in terms of usability or learning [12, 18].

In those cases, the result of a specific interactive installation's evaluation - conducted by experts from different research fields - can be very different. This problem can be solved by the introduction of a set of evaluation dimensions that allow obtaining very similar results, even when applied by researchers with different backgrounds to the same interactive installation or set of installations.

A FRAMEWORK FOR INTERACTIVITY IN MUSEUMS

The ultimate goal of this research is to develop an effective framework for evaluating the interactivity level of museum installations. This framework must stand on a specific and reliable set of parameters in order to obtain results that reflect the actual reality of the museum in terms of interactivity, also determining the interactive level of its installations that may vary from *very weak* to *very good* or *excellent*.

The framework can also be used to evaluate and compare several museums simultaneously, through an easy and visu-

al way that condenses relevant information like the classification obtained in each parameter, the quantity of interactive installations and so on. Additionally, it becomes possible to identify the strengths and weakness of interactive installations in museums and identify concrete areas for future improvements, which is something that professional interaction designers really need.

FRAMEWORK DEVELOPMENT

In a first stage, we performed a process of identifying and defining values and principles (that we coined as "dimensions") of evaluation, promoting a reflective and interdisciplinary approach to museums interactivity evaluation.

The usability evaluation process suggested by L. Constantine [4, 5] was adapted to the museum context and interactive installations and complemented with relevant parameters from the museum studies field [6, 7, 14, 15, 19, 23, 26]. A pilot trial was conducted in two museums. After this initial assessment, it was necessary to include a 5-point Likert scale for each evaluation dimension of the framework. The framework was then refined taking feedback into account. Three different framework users – all experts in user interface design and museology – tested the accuracy and reliability of the results obtained. In fact, after performing independent evaluations to several museums, the users of M-Dimensions reached similar results. As we mention in the following section, the results were replicable, although some small variations in individual rates for different parameters were obtained.

How to apply the framework?

The framework was coined "M-Dimensions" (M stands for Museums) and is composed by ten dimensions (interaction style adequacy, area integration, visibility, feedback, structure, reuse, simplicity, education, entertainment, collaboration), which are evaluated individually by a 5-point Likert scale (1: *very weak*, 2: *weak*, 3: *reasonable*, 4: *good* and 5: *very good* score). The goal is to rate each dimension, sum the scores and, finally, divide by the number of dimensions being considered in a specific interactive installation. The result is a final evaluation score between 1 and 5 that is meant to convey the level of the interactivity quality that is present in a given museum interactive installation. For example, if the final result of a specific installation is 1, we can state that the installation is interactively very weak. On the other hand, if the final result of the evaluation is a 4 or a 5, we can assert that the specific installation is good (or very good) in terms of interactivity. In this section, we will describe the framework's dimensions and exemplify the evaluation process.

Interaction Style Adequacy

The first dimension is aimed at evaluating how adequate is the interaction style of an interactive installation, considering its goal. Depending on the style of interaction employed, the installation is more or less difficult to use, and the visitor feels more or less tired when using it. Moreover, it is important to evaluate if the style of interaction is related with the information content and the museum atmosphere, improving or not the engagement of the visitor with the module.

For example, the most common format for displaying historical events and dates is the timeline organization. Therefore the utilization of an interactive timeline with touching gestures for displaying historical events and dates will be rated with a 5 score (*very good*). In this particular case the interaction style is intrinsically related with the information content. This allows a total understanding of the idea / content exposed, increasing the visitor knowledge while interacting entertained with the interactive installation. Generally, the level of visitor engagement is high.

On the other hand, an interactive installation that obtains a score of 1 for this dimension has an interaction style not well related to the information content of the installation. Therefore, the visitor will become easily tired of interacting with the installation and the level of engagement will also be very low.

Area Integration

This dimension classifies the installation's degree of isolation regarding the subject matter and whether the narrative of the exhibition is maintained or fragmented.

For example if the interactive installation is perceived as a totally independent information provider, producing isolation from the spatial context 23 and it distracts from the contemplation of the works of art, it should be classified with a score of 1 (*very weak*).

In order to be classified with a *very good* score (5), the installation at stake should perfectly fit the narrative and the spatial context, physically close to other related elements that complement and contextualize the interactive installation. The focus of the visitor will be the work of art/content and not the technology.

We illustrate this parameter through a concrete example. Figures 1 and 2 illustrate an example of two multi-touch screen kiosks from a museum in Madeira Island, *Madeira Story Centre*. They show both kiosks surrounded by allusive elements to the addressed subject, namely Portuguese ships history and construction (Figure 1) and trade and export of goods (Figure 2). It is also possible to verify that these kiosks are perfectly fitted to the narrative, which is complemented with related sounds and ambience music. Considering this analysis, these installations were rated with a score of 5 (*very good*) in this particular dimension.

Visibility

Visibility has been described as being able to show users whatever they need for the task at hand without distracting or overwhelming them 5.

In a museum context, the visibility of an installation is essential to its success, so that museum visitors can effectively use it. Therefore, in order to obtain a good score in this dimension, the module must be in a visible place where all

visitors can see it. Moreover, its disposition must encourage its usage and it must be identified with a title or labels to facilitate the interaction.

In our framework, highly rated installations provide immediate interaction capabilities and the visitor shows no hesitation, because all the elements needed are visible and available, without the presence of distracting objects. If there are too much distracting and unnecessary elements – either physical or digital – in the installation, the visitor will not be able to use it in an effective way, so his user experience cannot be as good as we wish.

Figure 3 shows an example of an interactive kiosk located at the Madeira Story Center museum's entrance. This particular installation obtained a score of 2 in the visibility dimension due to several factors. One of these factors was the high luminosity where the installation is situated, which makes difficult to see the content, especially because of reflections on the screens. Also the buttons are not properly identified and the font of the screen difficult the text reading. Another determinant factor for the low score in this dimension was the physical location of the installation itself. It is in a lateral location of the entrance barely visible, since most of the visitors enter through the reception (front way) without turning their heads. Moreover, the installation is very close to the glass, which separates the museum building from the outside, where cars and people are constantly passing by. Since this situation can be very distracting, the visitor may not interact properly with the kiosk.

Figure 1. Interactive kiosk about Portuguese ships history and construction at the Madeira Story Centre, Portugal.

Feedback

The feedback dimension establishes that the system should always keep users informed about what is going on, through appropriate response within reasonable time 20. This implies that a museum installation must effectively inform the visitor of events, results, progress, state changes and the remaining information that the visitor needs to complete the desired task while interacting with installation. At this point, the user interface must show useful information recognizable, understandable through visitor language.

Here we can think about modules with buttons. If the user press a button, the module must inform the action triggered by that button in some way, like lighting up a led, changing the screen, make some sound and so on.

An installation that does not clearly show its changing state may hamper its usage, as the visitor may not understand the interaction flow. In this case, this particular installation must be classified with a very weak score (1) in this dimension.

Figure 2. Interactive kiosk about Portuguese trade and export of goods at Madeira Story Centre museum, Portugal.

Figure 3. Interactive kiosk showing a low score in visibility.

Structure

Generally speaking, structure is about deliberate organization that reflects the intrinsic or familiar organization of things: things that are similar or related are supposed to resemble each other. Things that are not, ought not 20.

Inside a museum, the structure parameter of our framework is related to the element organization or arrangement inside the installation or between similar installations. In other words, this parameter deals with the layout, format, visual associations and distinction of the installation's elements. Related things should appear to be *related*, by being close to each other or by using visual connections or grouping,

like colors or boxes. Unrelated things should appear distinct by being distanced or by using visual separation cues.

The elements – font type and style, colors used, type of images, etc. – must have quality and be consistent inside the installation or between similar installations. This will facilitate the recognition of identical objects and promote behaviors that will turn the interaction more pleasant. Finally, the structure parameter can be summed up in consistency maintenance either within the module or between similar modules.

An installation that conforms to the above standards – consistency, good organization and so on – should be classified as being good (or very good), with a 4 or 5. Contrarily, an installation that does not will obtain a very weak evaluation for this dimension.

Reuse

Reuse is about recycling visual elements and interaction patterns so that interfaces are not only consistent, but also contain fewer distinct things to understand and master 4.

The reuse parameter evaluates the reuse of elements and behaviors inside the installation or between similar installations. If the museum visitor is not required to "rethink" or "remember" the interaction method (he will simply recognize) then the entire experience will become much more rewarding in every aspect.

Following the same evaluation approach, an installation that reuses elements in an effective way should be evaluated at least as *good*. On the other hand, a set of installations that never reuse elements should be classified as *very weak*.

Imagine a particular interactive module with a big red button used to hide the content shown in a specific moment. In this module, this red button must not be used to do anything else than hiding the content when pressed (behavior reuse). Otherwise, the visitor will get confused and is forced to "rethink" or "remember" that there is a particular situation in which the button does not hide the content but plays a sound.

Simplicity

Simplicity can be confused or wrongly used as a design principle. Simplicity should be about genuine elegance and parsimony rather than "simple-minded reductionism" 26.

Simplicity can be affected by many factors, such as lack of identification of the installation, lack of tips for using, unexpected behaviors, malfunctions and so on.

In order to obtain a *good* or *very good* classification in this parameter, the interaction with the module is immediate and successful during the time of use by the most of the visitors (90% to 100%).

For example, consider a multimedia kiosk where the visitor can navigate through the content and learn about a specific matter. Although well identified, with title and captions the module needs to be activated but is not clear how (tips or brief explanation). Most of the visitor can not understand where to start the interactivity at first sight, making difficult the use of this specific module.

Learning

Change is pervasive in contemporary museums as they are shifting slowly from places of education towards places for learning, responding to the needs and interests of visitors. Learning is about free choice (what the visitor will pay attention, when and how), seeking challenges and informal environments 7, being the learning dimension a key reason for people visiting museums 14. When inside a museum, interactive installations should promote critical thinking and questioning, with programs that raise questions, and addresses both facts and ideas 14. Moreover it is expected that the visitor will have access to multiple points of view to enable them to reach their own conclusions and make their own meanings based on their experiences and interests [11, 14]. Therefore an interactive installation that is in agreement with the previous description – free-choice, seeks challenges, addresses multiple points of view, etc. – engaging actively the visitor and enhancing his curiosity should be classified as being good (or very good) with a 4 or 5. Contrarily, an installation that does not make the visitor feel attracted to interact with, should obtain a very weak evaluation for this dimension.

Entertainment

Entertainment is another key point of interactive modules evaluation as museums currently compete in an expanding leisure marketplace 19. Their goal is to create participatory experiences that promote fun and allow the visitor to see new and interesting things in a relaxing and aesthetically pleasing setting 6. Therefore, a very entertaining installation is pleasant to use and interact with, increasing the level of engagement and time of use.

Generally, this dimension is evaluating observing some visitors using the module. It allows understanding how involved and focused they are in the interactive module use. Eventually, evaluators can use the time spent on interaction as a clue of the level of engagement. The longer the visitor passes interacting with the module, the higher the level of engagement.

Collaboration

One of the reasons that visitors go to museums is the opportunity to enjoy a social experience 2 as they can visit the museum with family, friends or others groups. It is a unique opportunity to participate in two-way communication with like-minded others 2. Therefore, an interactive installation that contributes to the dialogue among visitors enhances their social interaction and promotes the collaboratively working and learning 14 will have a strong collaboration dimension.

Nowadays user interfaces remain mostly individual, so for this dimension, we established that in order to obtain a score equal or lower than 3, only one visitor could use the

installation at a time. However, this may vary if the visitors around the user can easily see and discuss the contents displayed in the installation. The more difficult to observe and discuss by other, the lower should the score be.

In this context, an installation is considered collaboratively good if it can be directly used by up to 4 visitors at the same time and others visitors can easily see the interaction and discuss its results among them. In order to be considered as excellent in terms of collaboration, the installation should allow its use for more than 4 visitors at the same time.

Table 2 shows an example of the table applied in the museum evaluation, with the ratings of every framework dimension as described previously.

INSTALLATION / DIMENSION	**Images of ancient Madeira island (XIX and XX centuries)**	**Old photo album of several people taken by the three "Vicentes" generations**	**Photo exhibitor (wood tabs) with photographs of famous personalities who visited the island**
	Touch screen (*digital* installation)	Photo album/ book style (*non-digital* installation)	Wood tabs (*digital* installation)
INTERACTION STYLE ADEQUACY	4	4	3
AREA INTEGRATION	2	3	4
VISIBILITY	3	3	2
FEEDBACK	3	4	4
STRUCTURE	4	4	4
REUSE	4	3	4
SIMPLICITY	4	5	4
LEARNING	3	3	2
ENTERTAINMENT	3	3	3
COLLABORATION	2	3	3
TOTAL	***3***	***4***	***3***
FINAL RESULT:			**3**

Table 2. Evaluation of the interactive level of photography museum "Vicentes", Madeira Island, which has three interactive installations.

LIMITATIONS AND AVANTAGES OF M-DIMENSIONS

In this section, we present the M-Dimensions' limitations of usage, and its advantages and disadvantages as a new systematic way to evaluate the degree of interactivity in museums.

Limitations

It was difficult to establish direct relations between the total number of interactive modules and the size of the museum's collection as very different types of museums with diverse collections were evaluated. These museums can be classified into two different large categories: on one hand, museums that are more focused on the preservation of works of art and they are object-centered, academic and static; on the other hand, museums that aim at building narratives in order to enlighten visitors and therefore are discourse-centered entertaining and dynamic/interactive 23. Although it was not possible to quantify the relationship between the total number of interactive modules and the dimension of the museum's collection in the museums analyzed, it was possible to observe that: i) while the former usually have a low number of interactive installation in their collection and the integration degree of the interactive installations in the exhibitions is small; ii) the later museums experiments different solutions using interactive installations.

Another limitation of this framework is that it can be somehow time-consuming, especially during the first trials. Nevertheless, it would be extremely important to apply the framework to other selected geographical regions in order to evaluate the level of museum interactivity around the world.

Advantages

One of the main advantages of the framework developed in this work is that allows the dialogue between specialists from different fields, namely human computer interaction, design and museum studies. After the concept of the different ten dimensions was established and the 1 to 5 Likert scale was adopted in the framework, it was easy to obtain similar results between users from different fields. The results were replicable, although sometimes small variations in individual rates for different dimensions were obtained.

Also this framework allows an evaluation of the interactive installation connected with their museum context. This holistic approach is particularly important for the museum studies research field, as it takes into account if the installation is properly inserted in the museum exhibition 23.

Another important advantage is that it is possible to obtain a general overview of the museum interactivity in a selected geographical region. It is very easy to compare the results obtained and straightforwardly identify the main strengths and weaknesses of the different museums analyzed as it will be described below.

Also at the development phase, using this framework facilitates the evaluation of interactive installations in museums in an objective way, obtaining reliable results. This represents a great help to those who develop this type of interactive installations, since they can evaluate if the module is adequate and meets the established goals, as well as *how* and *what* they can improve in it. Moreover, this framework can be applied several times along the installation's development and design, in order to improve it, as well as to stimulate discussion among several experts in brainstorm-

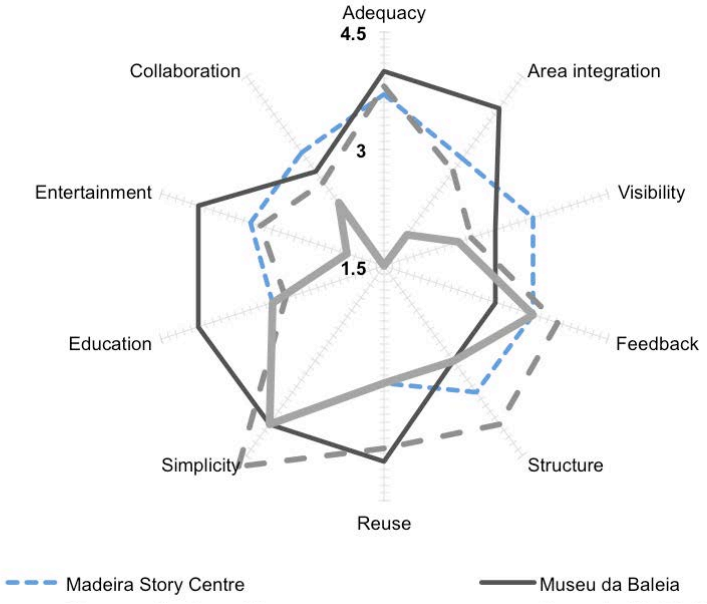

Figure 4: M-Dimensions allows a visual spotting of improvement areas as well as easy comparison of different museums.

ing sessions, for example, in order to obtain new and valuable ideas.

Finally, the designers may use the framework's results with the museums clients. This allows some feedback about how well the installation or exhibition is working. Also it can give some clues about main issues to improve in order to enhance the success of the installation.

USING THE FRAMEWORK IN A LONG TERM STUDY

Madeira, a very well-known Portuguese island which is visited every year by circa one million tourists, has 24 unique museums officially listed and published 17 related with ethnographic objects, painting, sculpture from different periods (15th century until today), natural history, sacred art, contemporary art, Island history, etc. (table 2).

Museum Name (Opening year)	Number of interactive Installations			Final evaluation using M-Dimensions
	Non-Digital	Digital	Total	
Museu Quinta das Cruzes (1953)	0	1	1	4
Photographia Museu Vicentes (1982)	2	1	3	3
Natural History Museum (1982)	0	2	2	3
Museu da Eletricidade – Casa da Luz (1997)	14	1	15	4
Madeira Story Centre (2005)	10	2	12	3
Núcleo Museológico de Machico - Solar do Ribeirinho (2007)	1	1	2	3
Whale Museum (2011)	0	15	15	4

Table 3. List of museums visited and analyzed with the M-Dimensions framework.

The majority of these museums were developed in the eighties and nineties and during the last five years were inaugurated two museums. Therefore, it was not a surprise that only seven museums (29% of the existing museums) featured interactive installations and that the number of digital installations per museum was considerably small (less than 15). This set of museums configured an adequate case study for our framework's expressiveness power, since it was possible to evaluate and verify in detail the accuracy and consistency of the information obtained with the framework developed in this work. Indeed, as there were few interactive museums in Madeira Island, it was possible to evaluate thoroughly each installation in each museum, by rating every framework dimension as described previously and exemplified in table 2.

Every interactive museum that we analyzed had installations with a reasonably good level of interactivity, as shown in table 3 and figure 4. The non-digital installations were very diverse as they promoted the application of different interaction styles (gestures, touching and motion-sensing) by the visitor. However, most of the digital installations employed the touch based interaction style. Both installation types, non-digital and digital, were particularly strong in terms of simplicity (figure 4) as the majority of the modules analyzed had user-friendly interfaces that could be learned easily by the museums visitors. Also the adequacy and the feedback parameter were particularly strong (figure 4) since the style of interaction was appropriate to the module content and the users could easily perceive the events, results, updates and all the information necessary to complete successfully the desired tasks. It was possible to verify that none of the analyzed museums had interactive modules collaboratively strong as they could not be used by more than four visitors at the same time.

USING THE FRAMEWORK TO AID THE DESIGN

M-Dimensions can also prove a useful tool for redesigning prototypes of interactive installations for museums. It can be iteratively applied along the design and development process, until a satisfactory result is obtained, which all stakeholders agree. At the same time, the rate obtained for each dimension give feedback for the teams involved, encouraging the dialog and guiding the process. In this section we will briefly present a new interactive installation that we designed, evaluated with the framework, redesigned and implemented in a museum. This installation uses motion sensors (the popular Kinect) to explain a set of antique prints performed by Andrew Picken (XIX century) according to the visitor's position and distance to a projection, illustrated in figure 5.

Figure 5. Initial version of our prototype.

By tracking body movements and distances, the visitor can interact with the installation in order to explore the different aspects of the antique prints according to distance planes.

Applying M-Dimensions, we were able to identify areas for improvement and to evaluate this initial prototype, which was redesigned afterwards. The table below summarizes the application of M-Dimensions. It also exemplifies a concrete case of how designers can use the framework.

DIMENSION	SCORE	EXPLANATION
Interaction style Adequacy	**1.1.1.1**	A good and adequate interaction style is used, since the visitor controls the content with natural movements of getting closer or farther from the antique print image.
Area integration	-	This prototype was not implemented in the museum, therefore this parameter was not evaluated.
Visibility	**2**	There are no captions or visual cues on the floor to help out the interaction. The font style can hamper reading. There's no indication about how to activate the usage of the interactive installation.
Feedback	**3**	The installation displays event changes (moving closer or farther away), when changing images, text or animations. However, the visitor doesn't know that there are several details of the paintings yet to be shown.
Structure	**2**	The quality of the images is low and the text doesn't stay aligned consistently throughout the different images.
Reuse	**4,5**	The different elements are reused throughout the user interface, following a uniform way.
Simplicity	**4**	The usage of the interactive installation is simple: the visitor controls the content according to his/her position and distance towards the projection screen.
Learning	**3,4**	The learning of new facts (historic facts, perspectives, locations and traditions) increases the level of education. Education is structured and informal.
Entertainment	**3**	The soundtrack and appealing graphics allow a greater feeling of immersion and entertainment, however the size of the display was not large enough to reach high levels of entertainment.
Collaboration	**2**	Only one visitor can use the installation at a time. Visualizing the entire interaction and contents by other visitors is possible, although with some difficulty because of the projected screen size, which should be larger, as well as the orientation and location of the installation.
Final result	**3 (*reasonable*)**	

Table 4 – M-Dimensions Framework applied to the initial prototype – Andrew Pickens Interactive.

The application of M-Dimensions allowed not only identifying areas for improving the interactive installation for this museum, but also as a basis for participatory design and common dialogue among all stakeholders. After this evaluation, the team redesigned the prototype taking into account M-Dimensions, as we show in figure 6.

The redesigned installation features automatic activation as soon as it detects a museum visitor nearby. Visitors interact by stepping left, right, forward or backward. Stepping forward or backward increases the distance planes and zooms in/out of the painting's details. Stepping left or right shifts the visitor through a map displaying the different paintings' geographical locations. There are labels and icons on the floor, to facilitate the interaction. A second evaluation was performed to assess if the redesign was indeed better.

This simple example demonstrates the expressive power of the framework and how it can act as a dialogue promoter between all project stakeholders. Visually plotting the results in a radar chart, as illustrated in figure 4, allows the team to identify areas for improvement and allows evaluators to compare several museums at the same time, in terms of interactive installations.

Figure 6: The redesigned prototype after evaluation using M-Dimensions. In the top figure it is possible to observe a high quality image, a legible font style, etc.

Dimension	Score	Explanation
Interaction style Adequacy	**3,4**	A good and adequated interaction style is used, since the visitor controls the content with natural movements of getting closer or farther from the antique print image.
Area integration	-	This prototype was not implemented in the museum; therefore this parameter was not evaluated.
Visibility	**3**	The font style is more legible. Titles are displayed. Some visual animations are easily visible while some are not. Captions are still missing.
Feedback	**3**	The installation displays event changes (moving closer or farther away), when changing images, text or animations. However, the visitor doesn't know that there are several details of the antique prints yet to be shown.
Structure	**4,5**	The quality of the images is now very good and the text stays aligned consistently throughout the different contents.
Reuse	**4,5**	The different elements are reused throughout the user interface, following a uniform way.
Simplicity	**3**	The use of the interactive installation is relatively simple: the visitor controls the content by walking left, right, forward or backward. However, during the initial usage, some visitors have some difficulty.
Learning	**4,5**	The learning of new facts (historic facts, perspectives, locations and traditions) increases the level of education. Education is more structured, as the visitor's curiosity is exploited and the control of the digital contents is more flexible.
Entertainment	**4**	The soundtrack and appealing graphics allow a greater feeling of immersion and entertainment, and the size of the display is now large enough to reach very high levels of entertainment.
Collaboration	**3**	Only one visitor can use the installation at a time. Visualizing the entire interaction and contents by other visitors is possible, although with some difficulty because of the projected screen size, which should be larger, as well as the orientation and location of the installation. However, comments among visitors were performed in this new version of the prototype, thus increasing the collaboration levels slightly.
Final result	**4 *(very good)***	

Table 5: M-Dimensions Framework applied to the redesigned prototype – Andrew Pickens Interactive.

CONCLUSION AND DISCUSSION

The evaluation framework proposed and described in this paper was designed through a long, lengthy and serious work of analysis and observation of several museums in different contexts and with different visitors.

The results were also very useful in many aspects, determining for example that the level of interactivity in Madeira Island's museums lies between the reasonable and good. Also, after implementing the proposed evaluation framework, it became possible to discover interactivity problems in Madeira Island's museums and also to outline possible solutions.

Furthermore, when applied to different museums, interactivity information can easily be compared in an interesting visual way, as we illustrated in the radar chart of figure 4. This also allows checking visually the strengths and weaknesses of each museum and it can be used for supporting decisions related with future investments for improving the interactivity level of museums.

Finally, for obtaining reliable results, it was created a set of guidelines, for rating each dimension with the Likert Scale. This makes possible the effective use of the framework by others than human computer interaction experts. Moreover, its results promote a constructive dialogue among experts in museology and interaction design, thereby building new bridges that will lead to more usable interactive installations in museums.

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