DIGITAL PUBLICATIONS OF THE

I SEA PROJECT

iSea

A Science Communication R&D project supported by

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I SEA PROJECT

Digital publications

Porto, October of 2020

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The I SEA Project

Digital publications

Porto, Portugal
October 2020
Faculdade de Ciências da Universidade do Porto

Credits

ISBN

978-989-746-279-5

DOI

10.24840/2020/978-989-746-279-5

Editors and copyright

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Website https://www.fc.up.pt/isea/

Financing by

FCT – Fundação para a Ciência e Tecnologia *Science and Technology Foundation*
República Portuguesa *Portuguese Republic*

Leading Institutions

Universidade do Porto *Faculdade de Ciências*
The University of Texas *at Austin*

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Program

UT Austin Portugal Program

Scientific advisers

IFREMER - Institut français de recherche pour l'exploitation de la mer

Graphics and pagination

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I SEA logo designed by ESAD *Escola Superior de Artes e Design*

Digital Publications of the I SEA PROJECT

MESSAGE

The I SEA project aimed at the development of a non-obtrusive, valid and replicable method to evaluate audience attitudes about science communication projects through an immersive virtual reality environment that can improve exhibitions while educating and empowering citizens.
To achieve the objectives of this highly complex, highly interdisciplinary, and innovative project, a permanent articulation of the scientific approach with the technical and design development took place, aiming the construction of the non-invasive evaluation method. Because it is an intricate project, it required constant iterations and interactions among the team members. So, we've learned somehow to consider limitations as engines for developing the project, instead of seeing them as obstacles.

Preliminary results from this exploratory project suggest that science communication evoked much-differentiated ideas, potentially signifying that its social representation is weakly structured. It is a meaningful, relevant, and essential activity for the researchers, consisting of sharing and communicating scientific knowledge. Even though society's apparent positive perception about science communication today, the audience and its role are not very visible in the representation, thus reinforcing the need to develop more efforts to make this field of study more structured and visible. This need is even more pressing given the necessity to communicate complex scientific information such as the information related to deep-sea ecosystems to the public in an understandable, actionable way.

As the main achievements or highlights of the I SEA Project, it is possible to point out:

1. Development of the narrative aimed at enriching the virtual reality immersive experience, attending to three fundamental points of the transformative game model: a) In a role-playing dynamic, participants took on the role of the protagonist, responsible for making decisions in the face of a dilemma - either for or against mining active/inactive hydrothermal vents in the Azores. This decision, in turn, conditioned the development of the narrative (person with intentionality); b) It was possible to understand and apply scientific concepts crucial to solving the dilemma presented in the narrative (content with legitimacy); c) A modifiable context was provided by the participants' decisions, emphasizing the consequences and meanings of these decisions (context with consequentiality). This narrative was translated from Portuguese to English so that the VR experience can be tested and replicated in the US context in the Fall of 2020 (depending on COVID-19 restrictions). Addictions to the transformative play had been suggested (need to relate with the flow theory and the need to include the participant's psychological identification processes with the virtual character).

2. Delimitation and development of a whole set of data collection instruments allow us, in a non-obstructive way, to obtain indicators about participant awareness, understanding, and involvement with deep sea ecosystems. Due to the robustness required for this instrument and its centrality to the project, it required an extensive validation process of the scales (content validation with the help of specialists, conducting focus groups, pilot applications, and statistical analyses, including factor analysis and internal consistency analysis) to test for the concurrent validity of the non-obstrusive method.

3. Perception of directors, monitors, and visitors of the Planetário and Expolab Centers, on how the non-obtrusive digital evaluation method, directly integrated into an exhibition, would work in a real context. That led us to carry out a significant number of interviews, followed by transcription and intensive content analysis to make sense of the wealth of data collected.

4. Usability studies focused on technological development and capsule design options that would be used in the virtual reality experience, taking into account necessary adjustments. Production of one animated infographic and two roll-ups that scientifically portray the water column and the entire ecosystem of hydrothermal vents, reinforcing the increased output of content to support the project.

5. Digital prototype in virtual reality environments. It was demonstrated at the Summer School ISEA (which took place in July 2019 at the Astrophysics Center of the University of Porto), with the participation of UT Austin partners. Production of the physical prototype. The two physical prototypes are installed as planned at Expolab and Planetário do Porto.

To disseminate the I SEA project, several publications were made. This document presents a categorized compilation of publications, including communications in international and national meetings and proceedings publication. Master dissertations, workshops, and round tables are also mentioned.

By the editors of this book

Carla Morais,
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The I SEA Project

The I SEA PROJECT

OVERVIEW

Evaluation has moved up the agenda in science communication. However, some procedures, while available, may be too obtrusive to use recursively in science centers and/or conflict with science center visitors' agendas. Our idea is to develop a non-obtrusive, valid and replicable method to evaluate audience attitudes about science communication projects through an immersive virtual reality environment that can improve exhibitions while educating and empowering citizens. We will embrace the Atlantic International Research Center agenda, specifically, deep sea ecosystems sustainability, by producing new digital content and carrying out pilot studies in local and national science centers.

The immersive virtual reality environment will have two modalities: for one person (individual condition) and for a group of individuals (collective condition), that will be supported by a game-based approach and multilinear storytelling. The journey will take visitors into extreme deep sea conditions, scaffolded according to three levels – a) awareness, b) understanding and c) engagement – regarding science/technology processes and contents: In the individual condition, the environment consists of a capsule with head-mounted displays and headphones to provide an immersive experience. In the collective condition, the digital environment will be projected full dome in a hemisphere room. In both cases, visitors will apply for a passport, choose a character and a mission. The difference is that in the individual condition the environment responds directly to the visitor's actions while in the collective condition it will mirror the consequences of the majority of choices. At the end, visitors receive a "deep-sea-gram", which is a short summary of their path through the game. More than delivering stories, the "deep-sea-gram" is expected to push visitors to create and share their own stories about their experience and to signify their relationship with the scientific endeavor. To develop a comparative framework, we will run several experiments to validate the method via within- and between-subjects plans.

GOALS & OUTCOMES

The project exemplifies the goals of the UT Austin | Portugal call in a few important ways.

First, it is an exploratory study with an emphasis on the scientific areas outlined by the Atlantic International Research Center, specifically deep ocean science, as well as CoLab Emerging Technologies Research, specifically digital media.

Second, it brings together an exceptionally strong collaborative team of researchers and practitioners from Portugal and UT Austin. These individuals represent a diversity of theoretical, methodological, and practical backgrounds, which translate into a strong foundation and allow scaffolding for future collaborations.

Third, not only does this project offer important insights for academic research and theory development, but it also offers vital practical implications, including the development of white papers on emerging technologies in new scientific areas as well as the potential for commercialization of the project's technological and communication deliverables.

Major outcomes of the collaborative work include the following:

- Creating a collection of digital content and messaging about deep sea ecosystems for science communication
- Developing immersive VRE as prototypes for other complex science phenomena
- Establishing a new, replicable non-obtrusive method for the evaluation of science communication in real world scenarios like science centers and museums.
- Reporting on best practices and recommendations for real-world applications
- Publishing in peer reviewed journals and conference proceedings
- Creating the foundations of a research line to foster new collaborative research projects in UT Austin | Portugal focused on the Oceans agenda.
- Working collaboratively, our aim is to establish an interdisciplinary, long-term cross-cultural research group to tackle pressing issues related to science and sustainability.

Our initial research endeavor aims to do this by examining lay audience understandings of deep-sea science and how these complex scenarios are communicated to and understood by members of the public. It is our hope that this first study demonstrates the utility of this kind of interdisciplinary, international research group so that we might extend the protocol to other issues of scientific importance, such as climate change, nanotechnology and clean energy.

Publications

Communications
in International
Meetings with
Proceedings
Publication

I SEA Project: Challenges from Science Communication and Evaluation Methods using Virtual Reality in Non-formal Contexts

C. Morais, J. C. Paiva, L. Moreira, T. Aguiar, A. Teixeira

Proceedings of the 12th annual International Conference of Education, Research and Innovation

Seville, Spain, 11-13 November 2019.

doi: *10.21125/iceri.2019*

Abstract

In formal education, evaluation is often an intrinsic part of learning. However, in non-formal contexts, such as science centers and museums, evaluation methods are usually invasive and conflicting with visitors' agendas. The I SEA project - a science communication project - intends to develop an immersive virtual reality experience (VRE – I SEA), combining science communication and its evaluation in the same experience, becomes a meaningful procedure for both visitors and institutions. The VRE – I SEA will be hosted at two Portuguese science centers (Planetarium and Expolab). Fieldwork on these centres was developed with the following goals: characterizing each center (i.e., mission, public, models of science communication), perceiving expectations and conditions for integrating the VRE – I SEA, acknowledging experience with virtual reality (VR), and learning their vision about communicating deep seas ecosystems contents. An interview script was developed to cover these themes. Two researchers visited both centers, interviewing a total of 10 intervenients (5 percent), among stakeholders, staff members, and visitors. Data were analyzed with NVivo and cross-compared to participant observation, field notes, and audiovisual records. Results point out different visions concerning the integration of the VRE – I SEA. In the Planetarium, a science center focused on space - astronomy contents, in Porto, most participants identified common characteristics in space and deep seas ecosystems exploration and between the immersiveness of the Planetarium's sessions and the technology to be used in the VRE – I SEA. In Expolab, an Azorean science and technology center, the location was one of the main themes referred by the interviewed when discussing deep-sea ecosystems. In addition, VR is familiar to this center, as Expolab provides VR applications to several science subjects. As for science communication, the analysis of the interviews and the activities available at the time of the visits show a prevalence of a deficit and a contextual model. In fact, personnel from both centers highlight the public's search for contact with the experts and the development of the public's scientific literacy as key points in their mission. Inferring from the viewpoints of the interviewees, what distinguishes science centers from formal education is exactly the absence of systematic evaluation. In addition, science evaluation is sometimes confounded as feedback, which neither of the centers seems to have implemented in a systematic manner. However, there are several attempts for public dialogue (through interactions at the end of science sessions) and obtaining of informal feedback. In sum, the centers' flexibility in integrating and justifying a new theme of deep-sea ecosystems is remarkable, however, considering that one of the I SEA project's purpose is to incorporate a method for science communication evaluation in non-formal contexts, these results lead us to challenge the current communication models in both centers. The I SEA project leads us to rethink the purpose of science communication evaluation, through the development of non-invasive methods, with benefits for both science centers and visitors. Also, the integration of science communication evaluation into the science communication channels may present an essential component towards a more dialogical communication model for science centers, replicable in other non-formal contexts such as museums.

Keywords: science communication, non-formal education, science centers, virtual reality, evaluation.

1. Introduction

Non-formal scientific education often takes place within science museums or centers, institutions, fairs or meetings, which intends to teach science to different types of public in a way that feels pleasant and that respects individuals' intentions [1, 2]. Today's techno-scientific society and ever-increasing digitalization also affect the ways and the spaces where science communication is carried out, as well as science communication itself. Given the importance of spaces such as museums and science centres in fighting the lack of science literacy in population [3], it is crucial to enrich these non-formal spaces with cutting-edge technology, such as virtual reality (VR), which is nowadays more available to creators and consumers [4]. Considering that context some questions can be asked: how well prepared are science centers for these media? And how are they planning to integrate virtual reality as a potential interactive means of communication within their existing missions and ways of communicating science?

With this work, we intended to characterize two Portuguese science centers and to study their expectations and conditions regarding the reception of a VR module about the deep sea within their usual exhibitions with a panoply of scientific modules.

In Portugal, the *Ciência Viva* Centers Network (CVC) [5] is the main national agency for the promotion of initiatives for public awareness of science and technology, in close association with public institutions and research laboratories. Currently, with 21 associated centers all over the country, the CVC aims at communicating science via interactive and experimental initiatives, directed to school and general public audiences [6]. The CVC mission is stated as to promote the general access to scientific culture, in order to attain the plenary exercise of citizenship, which goes in line with the desired outcomes of the contemporary definition of science communication. According to this definition, science communication is the use of skills, media, activities, and dialogue to produce one or more personal responses to science - awareness, enjoyment, interest, opinions, and understanding [7]. The approaches for putting science communication into practice are varied, generally following stablished *models* of science communication that range from those favoring unidirectional communication to those which rely on bidirectional communication (Fig.1) [8]. The *deficit model* assumes the existence of a deficit of knowledge about science within the public and full knowledge of it within scientists, therefore favoring communication from science experts to laypeople. This model does not consider the public's context nor their lay expertise, which is considered in other models – like the *contextual model*, that considers personal and social contexts, trying to construct messages about science which are relevant for a certain audience. Nonetheless, this model still assumes that scientists hold full knowledge of science and does not consider the expertise that the public might have with scientific issues, making way for the *lay expertise model*. Also, the model recognizes that the public might have local or lay knowledge of science within themselves, adding real-world, personal or policy significance to scientific knowledge. Finally, the *public participation model* emerged as a way of enhancing public engagement with scientific and technological issues, driven by the goal of democratizing science, either by giving some of its' control to public groups, or merely by stimulating dialogue between the public and science experts [8]. In the CVC, there has been identified a predominance of the contextual and deficit models, but also some signs of approximation to the public participation model [6, 9].

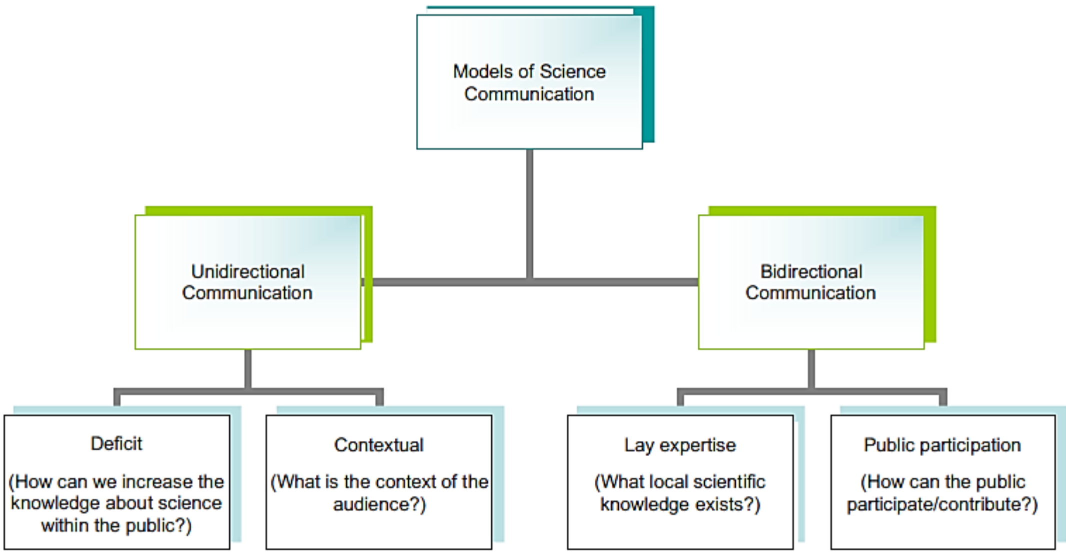

Figure 1: General scheme of current models of science communication (based on Lewenstein [8]).

Science communication has not only been evolving in terms of ways of action but also in terms of media employed, trying to keep pace with recent technologies of multimedia communication. Yet, while multimedia is marking a presence in CVC, the case is different for VR, as only 5 of the 21 centers affirm to be using VR, and only 3 actually own VR glasses [6, 9]. VR has been stated as owning several advantages for the transmission of scientific content, as it can change the abstract to the tangible, support doing instead of watching, substitute impracticable methods such as expensive field trips, and allow for the breaking of the bounds of reality as part of exploration [4]. Also, by definition, VR is a presential, immersive, and interactive means of communication, which, considering the communication of science via interactive and experimental initiatives privileged by the CVC [5], would lead us to expect to have more of VR based modules at these centers.

Hopefully, science communication will produce a series of personal responses to science, becoming essential to understand the nature, intensity, accessibility, and direction of changes. Evaluation of science communication should encompass practices carried out in science. However, usually available evaluation methods have been relying on long questionnaires and have been classified as too invasive and incompatible with visitors' agendas, highlighting the need for less invasive methods [10].

The I SEA project - a science communication project - intends to develop an immersive virtual reality experience (VRE – I SEA) that mimics a journey to the deep seas of Azores; but most importantly, this VR deep sea science communication will be happening alongside with an evaluation of the outcomes of the communication, therefore encouraging a meaningful experience for both visitors and institutions.

As this VRE – I SEA will be held at both Planetarium and Expolab, this work intended to take a closer look at these two science centers, trying to answer the following research questions:

- How the science centers Planetarium (Porto) and *Expolab* (Azores) characterized? (what are their missions, their public, their applied models of science communication?)
- What are the science centers Planetarium (Porto) and *Expolab* (Azores) expectations and conditions for the accommodation of the VRE – I SEA?
- What is the interplay between science centers' portrait and the expectations and conditions for the accommodation of the VRE – I SEA?

In order to answer these questions, visits, and interviews with several personnel members of both science centers and with their visitors was carried out.

2. Methodology

2.1 Participants

Science centers Planetarium (Porto) and *Expolab* (Azores) will exhibit the VRE – I SEA and hence they were contacted and invited to participate in this study. While the Planetarium is mainly focused on communicating astronomy contents, *Expolab* takes on a broader spectrum of scientific contents, from biology to physics, to newer technology applications and hands-on laboratory experiments. For each center, several elements of the personnel were recruited to be interviewed, encompassing stakeholders, staff members, and visitors. A total of 10 participants contributed to this study, five per center. In both cases, one stakeholder, two staff members, and two visitors were interviewed. Both interviewed stakeholders were male, the one from Planetarium having an academic background in Astrophysics and the one from Expolab with an academic background in Botanic and Museology. The two staff members at Planetarium were both male, one with academic training in Teaching of Astrophysics and coordinator of the dissemination unit of the Astrophysics Center of the University of Porto, and the other with academic training in Physics and the designer at the Planetarium. The two staff members at *Expolab* were male and female; one had a PhD in Biology and was coordinator at the center, the other had a degree in Informatics and was a higher technician at the center. As for the visitors at the Planetarium, one was male, holding a master's degree in Electrical Engineering, and the other was female, had academic training in Photography and Documental Cinema. Both were visiting with their families. At *Expolab*, the visitors were one female preschool teacher, which was visiting with a school group, and the other one was a couple of an architect (male) and an Electrical Engineer (female), who were visiting with their family.

2.2 Instruments

Two types of semi-structured interview scripts were developed, being adjusted to the types of interviewees – one script for directors and employees, one for visitors. The script for directors and personnel had a total of 7 dimensions, and the script for the visitors had 5, as Table 1 clarifies.

Table 1: Dimensions of the semi-structured interview scripts according to the intended audience.

Dimension	Question example	Intended audience
Expectations and experiences with the science center	*What are your expectations regarding your visit to this science center?*	Visitors
	Can you tell us a little about your visit to this science center?	
Presentation and Expectations regarding the VRE – I SEA	*What do you expect of the implementation of the I SEA module at this center?*	Directors/personnel
	What do you think of this type of project?	Visitors
Integration of the VRE – I SEA	*In your opinion, which would be the best way to integrate the I SEA module at this center?*	Directors/personnel
Virtual reality	*Have you ever had a VR module at this center?*	
	Can you tell us about your experience with VR?	Visitors

Characterization of the science center	*How do you characterize this center?*	Directors/personnel
Characterization of the science center's visitors	*How do you characterize the public that visits this science center?*	
Science communication	*What comes to your mind when you think about science communication that is made at science centers?*	Directors/personnel
	What is, in your opinion, the importance of science centers to the dissemination of scientific knowledge?	Visitors
Deep sea	*Can you tell us about your experience or personal view on the topic of the deep sea?*	Directors/personnel
	What do you think about the topic of the deep sea?	Visitors

2.3 Procedures

After an initial outline of the overall themes to be covered during the data collection phase, semi-structured interview scripts were developed and adapted to the types of future interviewees [11], following the methods used in previous works of the same type [6, 9, 12]. Later, after contacting the science centers' personnel and scheduling dates, two field trips were made to each center, with the goal of registering space details such as building plans, opening hours, entrance prices, types and formats of current expositions and multimedia materials available. These details were registered via field notes and audiovisual records. During these visits, the researchers also conducted interviews with the personnel and with some visitors present at the centers during that time, following the semi-structured interview scripts created for the effect. The overall course of the interviews had the following steps:

1. Personal presentations and explanation of the interview's objectives;
2. Reading and signing of the informed consent allowing for the collection of data;
3. Brief presentation of the VRE – I SEA, including narrative and, in the personnel's case, physical module, dynamics of operation and required human and technical resources;
4. Interviews, with audio recording;
5. Transcript;
6. Coding and discussing iteratively among researchers.

2.3.1 Data analysis

The recordings of the interviews were transcribed and later analyzed via thematic content analysis [13], using the software NVivo, and cross-compared to participant observation, field notes, and audio-visual records. When appropriate, the excerpts of the responses were categorized. The main categories were previously established, corresponding to the main questions posed in the interviews. However, new categories, that emerged from some questions or themes, spontaneously mentioned by the participants, were also explored. Thus, although some of the categories have been established *a priori*, in the analysis of the transcripts, emerging themes were also sought, in a shuttle analytical process, aiming to discover the nuclei of meaning [14].

3. Results

Several categories emerged from the content analysis of the interviews, mostly – as expected - converging with the main themes of the project, namely: the VRE – I SEA; the VR technology; the deep sea; and science centers' mission and activities in connection with CVC, the typical audience and the prevailing models of science communication in the targeted centers. In Figure 2, we represented the interrelations among categories. It is worth noting that the categories that are shared by participants from both settings are in blue; while the ones that are only mentioned by participants from Planetarium are in dark gray and the ones from *Expolab* are in pink. Ellipses represent *a priori* dimensions or settings while the rectangles represent emergent categories.

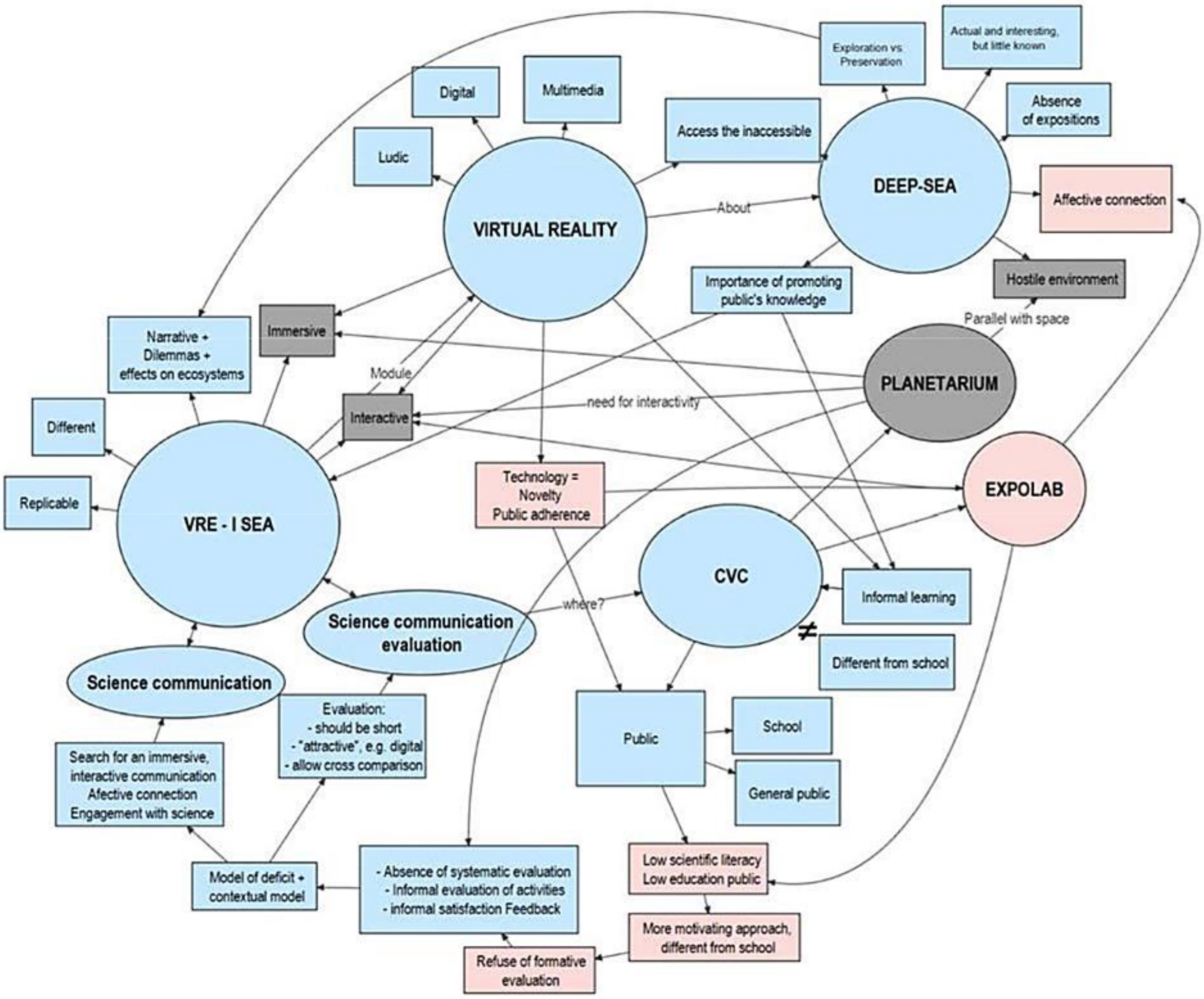

Figure 2: Content analysis categories.

The characterization of Planetarium and *Expolab* describes two very different science centers, only comparable in their association to the CVC. Planetarium results from "a synergy... between the center of scientific promotion… and the investigation center [in Astrophysics]" (P_D), which translates in "scientific rigor… ongoing knowledge" (P_C1) and "interaction with experts" (P_C1). Their main foci are the full-dome astronomy sessions ("*Planetarium… a special movie theatre…*", P_C2) and the laboratory sessions for school groups ("*specifically for schools, we have the laboratories or educational workshops…*", P_D).

In its turn, the *Expolab* has a broader thematic approach to science and technology, offering a variety of activities ("*we didn't expect it to have such a variety*", E_V2) – interactivity ("*that who visits the Expolab doesn't leave without making an experience at the laboratory...*", E_C1) and technology *("… we have a room dedicated to technology and we have augmented reality modules and virtual reality…*", E_C1) are their main ingredients.

Both centers personnel describe essentially two types of visitors: school groups and the general public. School groups are their main visitors ("*our biggest portion is school audience*", E_C1) that expectedly find in Expolab different means of approaching the school curriculum ("*the school audience, that comes with the teachers, comes with the aim of approaching themes that would be taught at school, in a different way, in a more motivating manner*", E_C2) and, in Planetarium, a closer contact with experts from astrophysics, astronomy ("… *here they are more in contact with scientists and therefore it will have more rigor, or that we won't fail…*", P_C1).

In comparison to school groups, general public is described as more diverse in attributes ("*we receive from children to adults, from unemployed people to university teachers*", E_D) and in expectations for visiting the centers ("*we have from entertainment, to not knowing what they are coming for, to specifically searching a theme they are interested in…*", E_C2). Stakeholders and staff in both centers consider children as the main motivation for seeking the centers ("*I think kids here, children, have a great role, because they end up passing the word to parents, grandparents, uncles...*", E_C1), which is corroborated by visitors ("*We used to come more often when my daughter was little*", P_V2). In addition, the general public is considered more difficult to appeal ("*General public is very difficult…*", P_D).

In *Expolab*, stakeholders and staff members also describe a local audience characterized by low scientific literacy and low education levels, infrequent visitors of science centers ("… *adults with low education levels that don't have the habit of visiting a science center or a museum… the scientific literacy is really low…",* E_C2). Therefore, the *Expolab*'s personnel consider captivating this audience a mission and a social responsibility, by being an alternative to school *("… we have been feeling that we have a great social responsibility*", E_D; "… *our main mission is the promotion of scientific and technological knowledge, especially and even more to those that are more distant from that knowledge*", E_C2). Also, in Planetarium, the interviewed describe their sessions as different from educational activities ("*and there is more by interest and not so much for education, it's more informal*", P_D).

This takes us to another important category of analysis, the communication of science. Analyzing the mission and activities in both centers, it is possible to conclude a prevalence of a deficit model ("*Generally speaking, we use a different model, that of a deficit, we know everything and we have a message to convey*", P_C1) – according to staff members and stakeholders, visitors search a closer contact with experts in Planetarium *("… researchers here participate a lot and people ask them and they answer*", P_V2) and an increase of scientific literacy while visiting the Expolab ("*So, I see many parents worried, trying that children have some scientific culture, some scientific literacy, and end up bringing them to* Expolab", E_C1). In consonance with a contextual model, both centers promote an adaptation of science communication to the characteristics of the visitors ("*When communicating science, I try to adapt to the level of the group whom I am communicating science to…*", E_C1). In addition, both centers practice a pleasant, visual, accessible communication ("*We try to simplify concepts, therefore using a simple language that people will understand*", P_D; "*Expositions that have more interaction, that have less exposed content, text… more images, more objects, more interaction*", E_C1), through immersive (in Planetarium), interactive (in *Expolab*) activities. On the way to a dialogical model, staff members in these centers engage in verbal interaction with groups at the end of specific activities ("*at the end we try to make a summary of the approached contents, and make questions*", E_C1; *"…we always have a staff member inside, and therefore there's always a part that is presented at the end and we try to have some interactivity*", P_C1).

Neither of the centers has implemented a systematic model of science communication evaluation, limiting their practices to collecting informal satisfaction feedback or informal evaluation of specific activities ("*in general, we don't do it systematically*", P_D; *"…we have some evaluation questionnaires for the participants…*", E_C1; *"… at the end one makes a little review on the subjects, and one realizes from children's interaction with their answers if they assimilated the knowledge or not*", E_C2). In the specific case of Expolab, this practice is confounded with formative evaluation that takes place at schools, which they consider as potentially demotivating for certain groups of visitors, and therefore, discarded ("*… we really try not to. So that they don't feed evaluated in that sense. So that it is different from school, different from other contexts, the person must feel free from evaluation*", E_C2).

The I SEA project emerges as a prototype for both communicating science and evaluating its effects on public's awareness, understanding, and engagement, without endangering the practices, activities and mission of these centers, as non-formal education vehicles. In fact, the VRE – I SEA is qualified by the respondents as: "a different module" (E_C2), with "*interactivity*" (P_V1) and "*immersiveness*" (P_D), allowing to communicate "*certain contents, mostly those of difficult access*" (E_D). Also "*interactive*" (P_C2) and "*immersive*" (E_D) is the technology used in the I SEA project – virtual reality.

Respondents in both centers conceive VR as (still) a new technology, with strong adherence from the public ("*We have a lot of adhesion to this type of technologies*", E_C1), associated with digital ("*This universe digitally build, with which the user may interact*", P_D) and multimedia ("*We can use multimedia to recreate a journey*", P_D), allowing to communicate cutting edge and "*inaccessible*" (E_D) science in a ludic, "*appealing*" (P_D) manner.

In fact, the I SEA communicates science on the Azores deep seas ecosystems, which, according to the respondents, is a "*very interesting, very contemporary*"

(E_C1), yet "*unexplored*" (P_D) theme. Common among the interviewed is the discussion between preserving and exploring the deep seas, which is addressed in the VRE - I SEA in the form of dilemmas, that the participants in the experience will face. According to one of the stakeholders, this is an ingredient of success that allows the "*understanding of the problem in its generality, and not just the scientific concept*" (E_D), validated by one visitor – "*choosing one or the other and… realizing the consequences… because people don't know what might happen*" (E_V2). In addition, there is common agreement on the general absence of expositions on the deep seas and on the little information that reaches the public ("*how will people achieve this knowledge? If even for scientists the information is still very limited... and therefore, what arrives at the public is even less…*", E_C2).

Taking into consideration Planetarium's and *Expolab*'s singularities, as well as the unique features of VRE – I SEA, it is crucial how these centers legitimate embracing the prototype. In Planetarium, the I SEA's immersiveness (associated with both the experience and the VR technology) is compared to the immersiveness of the full-dome sessions ("*Both this module and the Planetarium work with immersive environments*", P_C1). In addition, most participants establish parallelisms between the space and the deep sea exploration *("… but deep seas exploration has some parallel, for example, with space exploration… they are both extremely difficult… both extremely hostile environments*", P_D).

In *Expolab*'s case, its location in one of Azores' island is an affective bridge to the VRE – I SEA ("*but the proximity to Azores… for us it has a great interest…*", E_D; "*it is important for all of us Azoreans, we have this curiosity to know more…*", E_V1). In addition, the I SEA project communicates science through virtual reality, technology that is familiar to *Expolab* ("*we have this calling for technology*", E_D; "*we have VR glasses always available for the public with diverse applications…*", E_C1), especially since they have been developing a VR application for exploring the Laurissilva forest ("*I have developed a virtual reality application, I went to the Terceira island capture images of the Laurissilva forest*", E_C1).

4. Discussion

In this research, we tried to characterize two Portuguese science centers which participate in the project I SEA [15] welcoming a virtual reality environment aimed at communicating and evaluating audiences' awareness, understanding, and engagement with deep-seas ecosystems. Besides this characterization, we tried to identify expectations and conditions for the accommodation of the VRE experiment. Finally, we tried to understand the interrelation between science centers' portrait and the expectations and conditions for the accommodation of the VRE – I SEA.

In line with the literature [9, 16, 17], the science centers participating in the I SEA project share some characteristics but also present relevant differences. The common ground is made of the original idea of the CCV network: making science accessible through hands-on activities [18], serving schools, families, tourists, and individuals. However, their very own foundation and institutional filiation are different. While Planetarium is the interface for science communication of a Research Center in Astronomy, *Expolab* is included in the network of science centers supported by the Autonomous Government of Azores. While the latter is aimed at natural sciences and technology, the former is aimed at astronomy. The institutional and geographical context of each center seems to have a relation with participants' social construct of science communication, in Latour's terms [19].

One could think that the VRE module disturbs the tissue of connections established by the participants, but this is only partially accurate. In a social representations' perspective [20], participants make sense of the proposal with their shared repertoire of knowledge. For example, in Planetarium, they anchor virtual reality in the experience of immersiveness of the fulldome, though they add to this the increased level of interactivity. Interactivity is an ever-renewed promise of multimedia, but it is also rooted in the DNA of science centers. The *Expolab*, in turn, has already some experience with virtual reality and, being a science center with a focus on technology, perceives technology as valuable in itself. We can recall the backward movement of the authors of the theory of domestication [21-23] because they claimed that the medium was often neglected in favor of the analysis of the content or the message [24].

Interestingly, school visitors are very important for both science centers, but their relationship with the audience has different tonalities. On the one hand, the *Expolab* promotes different, complementary approaches to the themes of the school curriculum; on the other hand, Planetarium emphasizes the contact with Astronomy experts. Actually, the picture is much more complicated. Because the general audience represents a small percentage of the visitors, Planetarium tried to make the connections with the curriculum more visible with consequences to the way workshops are implemented. *Expolab* needs to design approaches to make scientific literacy a means of social inclusion. Though this is not the place to discuss this point, we want to emphasize the need to cross-compare discourses and activities. In fact, while the activities of Planetarium become more school -like (at least in the workshops), it seems that *Expolab* tries to make them more informal, intensifying the difference towards school. The discourse about science communication suggests the prevalence of the deficit and contextual models [8], which corroborates other studies and seems to reflect other centers perspectives as well [6, 9].

The contemporaneity of the deep seas is considered both a compelling and intriguing phenomenon, about which little information is currently disclosed. Besides, it requires a knowledgeable public for informed decision-making concerning the Azores deep seas. This is in line with recent studies of our research group on marine litter and the social representations of oceans and deep seas among laypeople [25-27].

The integration of science communication and its evaluation in the same process seems to praise our respondents, as it presents a non-invasive and ludic manner of evaluating communication's impact on visitors and reflect on it. Taking into consideration that neither of the centers seems to have systematic science communication evaluation practices implemented, the VRE – I SEA presents an alternative to the available invasive methods, replicable to other phenomena.

When analyzing the interplay between the science centers' characterization and portrait and the expectations and conditions for the accommodation of the VRE – I SEA, the VRE – I SEA seems to be in conformity with both center's call for an immersive, interactive, affective experience that communicates science, in a non-formal way, alternative to the formality of the school environment. To justify the integration of VRE – I SEA, the respondents, resorted to isomorphs of scientific and emotional order. These examples demonstrate the centers' flexibility in welcoming the VRE – I SEA, however, considering that the I SEA has a double purpose of communicating science and evaluating science communication, one must challenge the models of communication currently prevailing in these centers.

In conclusion, this prototype may pose an alternative to both the public's sparse knowledge on deep seas, communicating this thematic through immersive and interactive technology, as to the centers' absence of systematic science communication evaluation. More importantly, by integrating communication and evaluation in the same meaningful process, VRE – ISEA contributes towards a more dialogical model between visitors and science centers.

Acknowledgements

Luciano Moreira is supported by the FCT grant: PD/BD/114152/2015. ISEA - Exploratory Research Project - UT AUSTIN Portugal Program - UTAP-EXPL/CD/0106/2017.

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Citation

Morais, C., Paiva, J. C., Moreira, L., Aguiar, T., & Teixeira, A. (2019) I SEA project: Challenges from science communication and evaluation methods using virtual reality in non-formal contexts. *ICERI2019 Proceedings* (pp. 4690-4699).

Multimedia and Virtual Reality into Communication Practices of Science centers: A Social Representations Perspective

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Proceedings of the 12th annual International Conference of Education, Research and Innovation
Seville, Spain, 11-13 November 2019.
doi: *10.21125/iceri.2019.1165*

Abstract

The goal of this paper is to understand the way multimedia and virtual reality are being integrated into the communication practices of science centers and represented by their directors or responsible personnel, from the perspective of the social representations theory. Through a three-phase, mixed- methods approach, we focused on the 21 institutions of the Portuguese network of science centers (*Rede de Centros Ciência Viva*). Phase I consisted of a documentary analysis of the science centers websites and Facebook pages, in order to draw a preliminary map of the activities, scientific areas, multimedia and virtual reality devices of the centers. In phase II, we surveyed 16 directors or responsible personnel of the science centers via an online questionnaire, to corroborate the results obtained in the documentary analysis and also to identify the role of multimedia in science centers and which of them had virtual reality activities. Phase III consisted of semi-structured interviews with six directors or responsible personnel of six science centers from North to South of Portugal to explore their social representations, as well as to obtain in-depth information about the role of multimedia, virtual reality and visitors in the science communication strategy of the centers. Data were analyzed with the support of Excel, SPSS, and NVivo. Results showed that exhibitions are the most common kind of activities, followed by laboratories and workshops. Physical-natural sciences were represented in more than 75% of the science centers; mathematics, robotics, and informatics were present in less than 50% of the centers; social sciences and arts were underrepresented. Whereas projection devices and computers were used in more than 80% of the centers, virtual reality devices, tablets, and touch screens were used in less than 15%. Results of phase II, besides corroborating data from phase I, showed that the integration of multimedia seems to be associated with different degrees of interactivity allowed for the visitor. Virtual reality devices were mainly used to demonstrate their immersive capability rather than to explore the specificities of the science contents. As for the social representations, we found that multimedia was associated with the integration of image and sound and anchored to learning purposes and young audiences. Virtual reality was defined as "simulation" and "reality that does not exist", therefore objectifying the concept of interactivity. It was perceived as a means to attract more audience. Though a central role was assigned to the visitor, contextualization seemed to be the more frequently adopted model of science communication. The findings suggest that, though multimedia plays a central role in the centers, it does not meet up the promise of allowing for higher levels of interactivity and public engagement and that virtual reality became the ultimate technology for making sense of interactivity and extension of reality. This study urges for a framework to promote a balanced integration of the multimedia with the activities of science centers to support the adoption of bidirectional models of science communication, in which evaluation is essential. This line of research is being explored in a science communication project (I SEA) by a multidisciplinary team. Based on the affordances and social representations of virtual reality, the main goal is to develop a non-obtrusive method of evaluation of science communication in non-formal spaces.

Keywords: multimedia, virtual reality, science centers, social representations.

1. Science Centers, Multimedia, and Representations

Given the technological changes of the last decades, the main question of this research is to understand the way multimedia and virtual reality are being integrated into the communication practices of science centers and represented by their directors or responsible personnel, from the perspective of the social representations theory, as a theory of communication. In our case, we interested in understanding the way the directors of the science centers represent multimedia and virtual reality because representations are not only about meanings but interconnected with practices.

1.1 "Ciência Viva": An inspiring idea for science communication

In the decade of 1990, the Portuguese Minister for Science and Technology launched a program for democratizing access to science. Besides funding experimental sciences at schools and campaigns of science communication, the program supported the establishment of a national network of science centers [1].

More than 20 years later, the Portuguese network of science centers "Rede de Centros Ciência Viva" comprehends 21 centers dispersed by the Portuguese territory, from the Azores archipelago to the inland districts [2]. Despite the thematic diversity and characteristics of the centers, the guiding idea is still the one lighted up by Mariano Gago: to make science accessible by asking people to put their hands-on [3], serving schools, families, tourists, and individuals [4].

The concern with the democratization of science is not new. Since the decade of 1970, different models of science communication were constructed [5]. The deficit model tried to fill the gap of scientific knowledge in the target audience; the contextual model implied attention to the audience's environment in order to facilitate the transmission of scientific information. The laymen expertise model revalues the knowledge heritage that the audience uses to solve problems. Finally, public participation models try to engage laypeople in the scientific process.

Regardless of the models, every message needs a medium. In the Portuguese Science Centers, multimedia devices and systems are used to convey messages and to engage the audience in the activities. This paper will try to show how the integration of multimedia in science communication is represented, but before we need to focus our attention on multimedia and virtual reality.

1.2 Multimedia and virtual reality

For Mayer [6] multimedia corresponds to the presentation of materials using words and images. Nowadays, it usually corresponds to digital information conveyed in more than one form, combining the elements of the multimedia array in a multiplicity of solutions. Because of the horizons multimedia opens, it has attracted scholars to study its relation with education [7], science education [8], and science communication [9].

Virtual reality is the ultimate type of multimedia system, although it is possible to locate its origins around the decade of 1960, with the multi-sensorial simulator Sensorama or with the Ultimate Display [10]. Virtual reality eloquently expresses the tension between, on the one hand, transparent immediacy and, on the other, visible mediation [11].

Despite virtual reality is not a new technology, in recent years we have been witnessing an increment of the interest and investment on the part of the game industry and a lowering of the price of the devices [12]. For understanding how is it that science centers in Portugal are integrating multimedia and virtual reality we need to understand how their directors or responsible personnel are making sense of these technological systems, reason why we will, briefly, review the theory of social representations.

1.3 Social representations

The theory of social representations is especially suited for the study of the transformation of scientific and technological knowledge into common sense [13, 14], even if for one reason or another this original vocation is very often neglected [15].

Social representations are the common ground that results from the symbolic exchange of social groups about things, and, vice versa, the ground that breed ideas and discussion with a plethora of meanings [13]. In a nutshell, it about the way knowledge is constructed and changes in time, by making novelty familiar [16].

Coping with novelty involves two processes: anchoring and objectification. People search for similarities between new things and their previous knowledge about other, more familiar objects, imputing a sort of equivalence between the old and the new: for example, computers initial were reduced to a typewriter [17]. However, once their distinctive feature, i.e., programmability was integrated into common sense, computers become things in their own right, serving as symbols in turn for the human brain [16]: they are objectified. Objectification is the process of render what abstract an almost if not material and tangible image.

Communicability between scientific language and common sense is what makes the study of social representations of science and technology relevant. For example, we now may use the word robot to characterize an athlete or the word virus to name an informatics malfunction [18]. Contrasting with areas such as natural science, metaphors used in Greek newspapers about engineering and informatics topics were located within a promise-scare axis [19].

2. Methodology

The mixed-methods approach was three-phase (a documentary analysis, an inquiry by questionnaire, and an inquiry by interview) and focused on the 21 institutions of the Portuguese network of science centers (Rede Ciência Viva). As the study narrows in the number of objects of analysis and/or participants, it grows in focus and detail, reflecting an intentional trade-off between the representativeness and deepness of results. The research was conducted as part of the Master in Multimedia dissertation of the first author [20] and was part of the Project I SEA [21].

2.1 Phase I – Documentary analysis of the science centers websites

Phase I consisted of a documentary analysis of the science centers websites and Facebook pages, in order to draw a preliminary map of the activities, scientific areas, multimedia and virtual reality devices of the centers. Websites and Facebook pages were identified by searching the web for the name of each one of the science centers; the authenticity of the online sites was checked. The content analysis grid focused on the typology and characterization of the activities (type, scientific area, multimedia) and the general characterization of the center. Data were analyzed with the support of Microsoft Excel.

2.2 Phase II – Inquiry by questionnaire of science centers responsible personnel

In phase II, we surveyed 16 directors or responsible personnel of the science centers via an online questionnaire, to corroborate the results obtained in the documentary analysis and also to identify the role of multimedia in science centers and which of them had virtual reality activities. The questionnaire was constructed on the criteria used in Phase I, including 12 questions. After a pilot test with responsible personnel from three science centers, the questionnaire was improved and made available in the LimeSurvey platform of the University of Porto. An invitation was sent to the email contacts of the science centers, and some personal contacts were also activated to increase the response rate.

Data were analyzed with the support of Microsoft Excel and IBM SPSS Statistics 25.

2.3 Phase III – Inquiry by interview science centers responsible personnel

Phase III consisted of semi-structured interviews with six directors or responsible personnel of six science centers from North to South of Portugal to explore their social representations, as well as to obtain in-depth information about the role of multimedia, virtual reality and visitors in the science communication strategy of the centers. While four of the science centers did not have experience of virtual reality available for visitors, other two have or have had such experiences available. Participants were contacted after declaring their availability in the previous phase. The recruitment was guided by the interest in listening to directors of science centers with and without virtual reality activities but was also constrained by the research schedule. Interviews were fully transcribed and analyzed in NVIVO 12, according to a two-level analysis: in the first level, we used emergent categories resulting from iterative readings and, in the second level, a priori categories, based on the processes of the theory of social representations (objectification and anchoring).

3. Results

Results from the documentary analysis of the Internet sites and Facebook pages of the science centers showed that exhibitions are the most common kind of activities, available in 19 of 21 centers, followed by laboratories and workshops. It is worth noting that the rest of the activities, such as lectures, conferences, movies, or field trips, are only available in less than 20% of the science centers.

Physical-natural sciences were represented in more than 75% of the science centers; mathematics, robotics, and informatics were present in less than 50% of the centers; social sciences and arts were underrepresented, which is coherent with the fact that only recently the Museu de Foz Côa, dedicated to archaeology, was included in the Ciência Viva network of science centers.

As for the multimedia available, whereas projection devices and computers were used in more than 80% of the centers, virtual reality devices, tablets, and touch screens were used in less than 15%.

Results of phase II, besides corroborating data from phase I, showed that the integration of multimedia seems to be associated with different degrees of interactivity allowed for the visitor. Virtual reality devices were mainly used to demonstrate their immersive capability rather than to explore the specificities of the science contents. Available in three science centers, it is used to allow the visitor to visualize and navigate by natural landscapes or to experiment free applications, only to promote a first contact with the technology

Phase III allowed exploring the social representations of the directors or responsible personnel of six science centers. Multimedia was associated with the integration of image and sound and anchored to learning purposes and young audiences. Virtual reality was defined as "simulation" and "reality that does not exist", therefore objectifying the concept of interactivity. It was perceived as a means to attract more audience.

From the comparison of the cluster analysis in Figure 1 (Science Centers with experience in virtual reality) with the one in Figure 2 (Science Centers without experience in virtual reality) significant differences emerge. Interviewees of the centers with virtual reality experiences seem to connect the word virtual with activities, in the inferior branch of the figure, where we can find references to the exhibitions and the visitors. In the other branch, which has two major divisions, it is worth noting that multimedia is associated with concern. Participants are concerned with the purposes of the multimedia, wanting it to

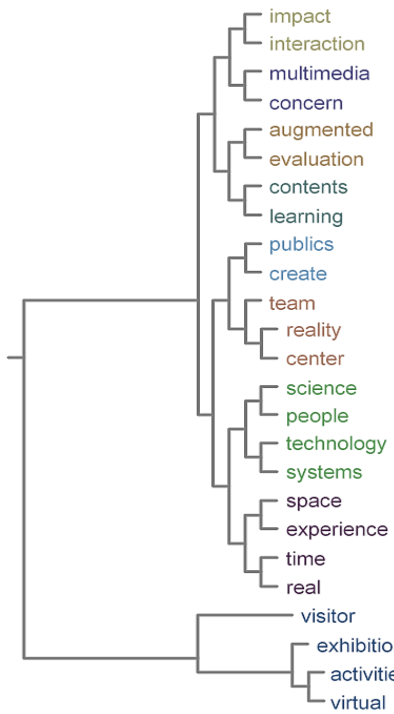

Figure 1: Cluster analysis of the interviews (Science Centers with virtual reality experience).

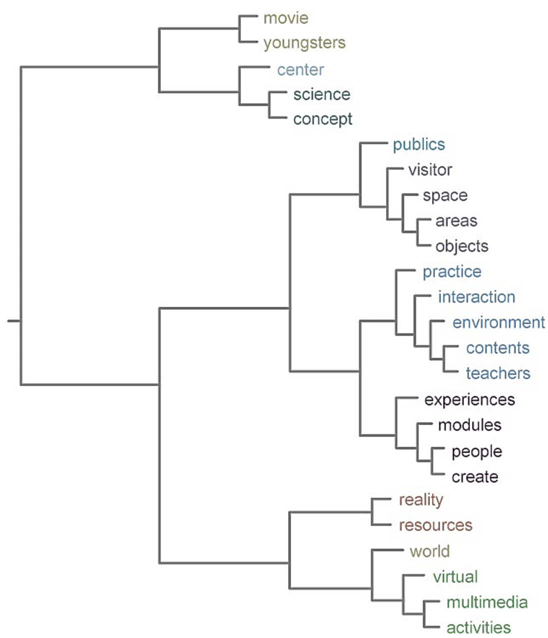

Figure 2: Cluster analysis of the interviews (Science Centers without virtual reality experience).

be more than attractive. In valuing the learning role of the multimedia, they express an anchoring of multimedia to education. In Figure 2, reality and virtual still appear in the same branch (inferior branch), together with multimedia, activities, resources, and world. Multimedia may be working in this case as an anchor to make sense of virtual reality. In other words, the degree of integration of multimedia seems to be lower.

The analysis of the mentions to the drawbacks or disadvantages of virtual reality corroborates the idea that practices are interplayed with representations.

In the centers that have experienced virtual reality, concerns revolve around the secondary effects such as sickness, and that the continued use of the system might have adverse effects on the long-term. On the other hand, in the centers that never have had experiences of virtual reality concerns are about the usability of the equipment (uncomfortable and not practical), doubts concerning their efficacy and the costs.

The headset, thus, seems to objectify virtual reality, making them visible and tangible. In this case, it seems to help centers without virtual reality to address the topic. Another evidence is the association of virtual and augmented reality. When the participants mention augmented reality, in 8 out of 25 times, they also mention virtual reality.

Multimedia seems to be anchored to young audiences, due to their supposed familiarity with interactive technologies, although some concern with the possibility of saturation effects are reported. Interactivity is an essential topic of the interviews, as participants stress that the centers should engage visitors by stimulating the dialogue with the monitors and by interacting with the science modules. Some types of multimedia, such as films, are questioned because they seem to promote one-way strategies of communication, assuming that all the visitors are equal. Virtual reality seems to cover this gap, allowing for interactive, immersive experiences that enhance or extend the world of the visitor. Technology itself almost become the center of the experience, because it is new for most visitors and also because there is a deficit of science contents for virtual reality.

Though a central role was assigned to the visitor, contextualization seemed to be the more frequently adopted model of science communication. Evaluation is mostly informal, consisting of feedback collected from the visitors.

4. Discussion

In this study, investigated the way social representations of multimedia and virtual reality through a three-stage mixed methods approach, conducting a documentary analysis of the webpages and Facebook pages of the Portuguese Science Center "Ciência Viva, a questionnaire and finally interviews with directors or responsible personnel.

The prevalence of computers, sound systems, screens, and projectors is in line with the idea of multimedia as a combination of sound and images [6, 7]. Novel technologies need to be tamed [22- 24]. The degree of integration of multimedia as a combination of sound and image suggests that the process of domestication for science communication is finished. However, if we think of media as remediation [11] and premediation [25], it seems that science centers are being quite conservative in the way their curatorial approaches and representations of the role of multimedia.

The findings suggest that, though multimedia plays a central role in the centers, it does not meet up the promise of allowing for higher levels of interactivity and public engagement. Virtual reality became the latest technology for making sense of interactivity and extension of reality, but the promise is not without danger or feelings of fear [19, 26]. Previous experiences with virtual reality seem to change the representation, showing the inseparability between representation and action [27]. In the present study, the discourse becomes more specific: actors are more knowledgeable in the sense of the practical knowledge referred by Jodelet [28]

This study urges for a framework to promote a balanced integration of the multimedia with the activities of science centers to support the adoption of bidirectional models of science communication, in which evaluation is essential. This line of research is being explored in a science communication project (I SEA) by a multidisciplinary team. Based on the affordances and social representations of virtual reality, the main goal is to develop a non-obtrusive method of evaluation of science communication in non-formal spaces.

Acknowledgements

Luciano Moreira is supported by the FCT grant: PD/BD/114152/2015. ISEA - Exploratory Research Project - UT AUSTIN Portugal Program - UTAP-EXPL/CD/0106/2017.

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Citation

R. Simões, C. Morais, L. Moreira (2019) MULTIMEDIA AND VIRTUAL REALITY INTO COMMUNICATION PRACTICES OF SCIENCE CENTERS: A SOCIAL REPRESENTATIONS PERSPECTIVE, *ICERI2019 Proceedings*, pp. 4746-4752.

Knowledge Analysis Automatic Evaluation in Virtual Reality Immersive Experiences

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Proceedings of the 2019 International Conference on Graphics and Interaction
Faro, Portugal, 21-22 November 2019.
doi: *10.1109/ICGI47575.2019.8955099*

Abstract

Museums and exhibitions usually attempt to evaluate visitors' obtained knowledge through the use of traditional evaluation methods such as questionnaires. These are intrusive and may not provide correct results, especially due to the fact that visitors are usually not interested in being evaluated and may consider such questionnaires as intelligence tests. This paper proposes methods of design and creation of automatic evaluation techniques that make use of Virtual Reality (VR) in order to evaluate users' obtained knowledge after playing through a VR museum game experience. This Analysis System is non-intrusive (its methodology does not impact users' immersion and engagement), valid (can draw conclusions regarding users' obtained knowledge), and replicable (designed techniques can be used in a variety of experiences). Results indicate that the designed assessment techniques can be used to automatically evaluate the knowledge obtained by users throughout the experience, as well as some considerations to keep in mind when designing game experiences with these techniques.

Keywords: automatic analysis system, interaction inter-faces, virtual reality, non-intrusive evaluation.

1. Introduction

Communication between science and scientists with the general population is utterly important. When someone wishes to learn about a specific topic, either because it is part of their education, work, or something they enjoy doing in their free time, one of the possibilities is to visit museums. But in recent years, the number of visitors has been declining [1], mostly because the population prefers to spend their leisure time doing other activities, such as enjoying the latest technological gadget. Museums exhibitions may also not be engaging going from exhibition to exhibition, reading information regarding the displayed artifacts may not captivate the visitor's attention, and therefore the knowledge acquired by the visitor may be lower than expected. When users are required to memorize knowledge without an actual engaging context, they tend to forget it after a while [4]. In a science museum, a specific process can be taught to their visitors, either by making them read about it or watch a video, but since they are not required to use that knowledge for anything other than memorizing it, that knowledge soon fades away since it is not stimulated. When the visit ends, museums may attempt to grade and evaluate the museum's experience and the acquired knowledge from a visitor, asking them to fill in questionnaires. These questionnaires are usually inconvenient and intrusive, since visitors do not feel the need to be evaluated, and most of the times they do not want to, especially if their visit was only out of curiosity.

To address this, one can look at the rise of popularity in virtual reality (VR) experiences [5], especially in the entertainment industry, with users being more aware of the technology than ever. Experiences developed for this medium allow the player to be immersed and engaged while they are interacting in the virtual world [6]. Games have also proven to be an efficient way of learning [7] since they provide an interactable environment for users to explore, succeed and fail without real-life consequences, empowering users to try anything they want [4]. Since they provide a more interactable experience, they can better engage and motivate the player than traditional methods, such as reading or watching documentaries [3].

By joining virtual reality with educational games, it is possible to address the lack of engagement that a museum may suffer from, providing users with a rich experience that focuses on the content knowledge that the museum has to share. If users can learn inside a VR experience, they can also be evaluated using that same medium, without the need for outside evaluation systems [8] [3]. A system that evaluates what the user learned and what they missed throughout the game could be used to conclude the amount of information provided to the user. This should be a non-intrusive evaluation system.

A new method to evaluate users when they interact with educational content is necessary, a method that does not remove the engaging aspect of a learning experience, that is non-intrusive and can actually make users learn in a situational context, rather than just through memorization. This work is part of the project iSea [14] for developing non-obtrusive, valid and replicable methods to evaluate audience attitudes about science communication projects.

2. Related Work

Many science museums try to attract their audience with the promise of interactive experiences inside the museum [1]. There have been many experiences in museums that use VR to support educational experiences. They vary from basic experiences such as viewing artifacts or virtual tours [10] to rich and immersive interactive games, which can target single-player [11] or multiplayer [12]. These experiences are focused on trying to teach users about a specific topic, but not necessarily in evaluating the knowledge users acquired or the exhibit experience itself. The British Museum held a "Virtual Reality Weekend" event [13] in 2015, allowing users to explore a scene during the Bronze Age, using the Samsung Gear VR. In this experience, users could walk around in the landscape using a touchpad on the Head Mounted Display

(HDM) and look around by moving their heads. Users could interact with certain objects, and in order to give clues as to which objects were interactable, those objects glow blue to highlight the fact that they were there for the user to know more about them. Users could select them by looking at them and by tapping the touchpad, changing to a closer view in which they were able to rotate the selected object while hearing a description. That description was the message that the museum wanted their visitors to learn, so the audio description had to be engaging and significant in order to avoid boring the user. Since the experience was not linear, users could walk around and interact with objects at their own pace, keeping immersion correlated to its main objective: providing knowledge. The evaluation from that weekend alone was great, with most visitors saying that the experience was good and that it provided a great opportunity to learn more about the Bronze Age.

The French National Museum of Natural History has a permanent exhibition with a catalog of VR experiences that change based on the museum's events. One of those experiences is called Journey Into the Heart of Evolution[1], in which participants can interact with a network of hierarchical species, by manipulating that network in 3D space, selecting the species that they wish to learn about, and details of that species are then presented to the user. It also has a mini-game regarding relationships between different species and a model viewer for each one.

Some of these experience also have systems to evaluate the user and their obtained knowledge. Garcia-Cardona et al. [3] developed an application that offered an immersive experience and evaluated users while they were playing the experience itself. The application allowed users to visit a portion of an ancient Aztec city, in which they had to explore the environment while answering questions inside the virtual world. Users wondered around the environment, guided through audio cues and interactive visual feedback (objects being highlighted), encountering several pop-ups referring to specific objects and/or scenes related to the Aztec city, which would present images or text information. Users could also find pop-ups presenting questions about the newly obtained information from the image/text seen before. To increase the user's motivation to complete all the questions available and explore everything the application had to offer, the authors implemented a scoring system as a positive feedback loop, in which each question answered had audios cues to inform the user if they answered correctly or not. Since the evaluation was actually inside the experience, answering questions would still be done in an immersive environment, so users would still be engaged even when under evaluation. Around 88% of users that went through this experience answered that the experience itself was more engaging than being provided the same information on a physical paper.

Allison et al. [8] wanted to teach students about gorilla interactions and the place each one occupied in the dominance hierarchy. They designed an experience in which students take on the role of a juvenile gorilla and must

[1] Journey Into the Heart of Evolution, 2017 (released year): https://www.mnhn.fr/en/explore/virtual-reality/journey-into-the-heart-of- evolution, Last accessed: 20/12/2019.

interact with other gorillas. If they approached an older gorilla in a threatening way or just stared continuously at them, the older gorilla would start to intimidate the user by, for example, beating his chest. If users insisted on continuing with the same behavior, they would leave the gorilla's interacting zone and move to a new zone, which is a metaphor for the species removal and reintroduction in a different gorilla group. In the beginning, users would completely ignore the older gorilla's warnings, resulting in the gorilla charging at them, and with users (as the young gorilla) being reintroduced in a new environment, but they quickly understood the warning messages from more dominant gorillas, keeping their distance from the stronger ones, which was ultimately the goal of the experiment. If users finished the experience by being constantly reintroduced into a new zone, then users failed in learning the fundamental information that the experience wanted to portray, but if they completed it by not being reintroduced after a long time, then they understood with success how to interact with the portrayed species, learning concepts of gorilla interaction and dominance hierarchies in an interesting and fun way, as stated by them after the experience ended.

3. Analysis System

In order to evaluate users through gameplay, the Analysis System (AS) must be able to be aware of their actions so that it can associate them with a specific conclusion. The AS must be able to detect what the user sees, what they do and how long they take to do it. The AS uses their overall interactions to evaluate what users learned or paid attention to.

The first metric to take into account is the user's gaze direction, which can give the AS information regarding what the user is looking at. Many applications that require the gaze direction for gameplay reasons usually display it as a white dot/circle in the middle of the screen, but in order to maintain the non-intrusive nature of the system, any information regarding the gaze should not be displayed, since the gaze is only used by the AS in order to detect the object users are currently focused at. By making use of this functionality, the AS can observe where the user is looking, and if they are looking at a specific point of interest (POI) that the system considers to be important or contains precious information that they can learn from, certain conclusions become possible.

Only using the gaze direction is not enough, as further analysis is necessary when drawing conclusions. If users just look at a POI momentarily, it is wrong to expect they learned the POI's intricacies, as there was not enough time for the user to fully analyze it. In order to improve on this, each POI should be focused by the player for a specific amount of time (acknowledge time), time that should be enough to carefully consider the importance of specific POIs located in the game's environment. Each POI requires a certain level of attention that is dependent on each one, based on their learning complexity. For instance, assuming there is a screen that displays important information that the user can learn from, in order for the system to understand if users learned what the screen portrays is to set its acknowledge time as the screen's reading time. If the user looks for that required time to the screen, then the system can assume that the user gave the screen enough attention as to understand and learn what was written there. This should enable the AS to more carefully conclude about the knowledge obtained by users when using their gaze direction since it requires a certain level of attention that is dependent

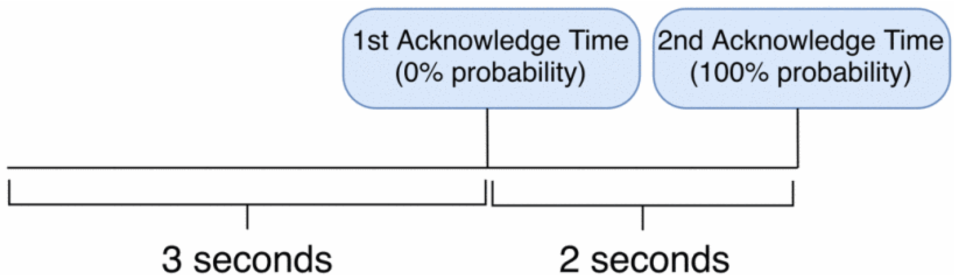

Figure 1: Acknowledge time with 2 thresholds. The probability of the user learn goes increases between the 3rd and 5th second.

on each POI. The moment users' gaze direction intersects a POI, the focus time starts counting towards the POI's acknowledge time, stopping counting when they stop looking at the POI.

It is possible to improve on this concept by associating different levels of attention to each object. Instead of specifying only a single acknowledge time in which users that looked for long enough are considered to have browsed the information and users that stayed under that acknowledge time are considered to not have browsed, by specifying, for instance, 2 acknowledge times, this restrictiveness can be mitigated (see Fig. 1). If users looked long enough to go over the first acknowledge time, the AS knows the user is somehow interested in the POI and what that POI has to offer in terms of information, increasing the probability of users actually learning about it, establishing a linear relationship between the amount of time looking after reaching the first acknowledge time and the probability of users learning the portrayed information. By continuing to focus on the object, the probability continues to increase, until it reaches the second acknowledge time, which is assumed that users should definitely have learned what the object has to offer. It is worth pointing out that this extra acknowledge time was not implemented, and thus not tested, but it is, nevertheless, and important suggestion for this metric.

Another important metric is interaction. Certain interactions may have an underlying objective: when the player interacts with an object and depending on the design of the experience, that can be an indication of awareness towards understanding what the experience portrays. The system should be able to detect when certain interactions take place, and if such interactions are important, it can conclude if users understood the knowledge that the experience wanted to present. After being taught how a specific interface works, when users use that same interface, they usually do so with a purpose in mind. For instance, the user is taught that by pressing a specific button, that button triggers an action that changes the game state. If, throughout the game experience, users press that button when that change to the game state is positive regarding a specific problem they are trying to solve, the AS can conclude that users understood when to press the button and use such functionality in the right moment.

One more possible metric to evaluate users is by measuring time. This metric can be used to understand how the player performed under certain situations, such as the time they took to complete a specific action. For example, if users take too long to execute a certain action, that can either suggest they did not understood how to use the required interface to perform it or that they lacked the ability to execute the required action. But if they performed the action in a short amount of time, that suggests they knew how to use the interface and had the ability to perform it. This metric can also be used to evaluate users' decision making: if they take an unusually big amount of time to decide, that can suggest users were careful when making their decision, taking the required time to measure all the different possibilities and their impact on the game world, as opposed to when the decision time is very short, suggesting that users' mind was set on a specific choice and they had no doubts about what they decided.

4. Implementation

The implemented solution is a VR experience with an incorporated AS that is able to attribute meaning to player's actions within the game. This AS operates according to the evaluation metrics described in the previous section. When users are immersed in the experience, the evaluation system works in a non-intrusive way, analyzing player's actions, classifying said actions, and in the end exporting this information to a file that can be read in order to verify what the user learned or not regarding the played experience.

In order to make this experience feel as a complete game experience, a lot of systems that react to one another had to be implemented, including the interfaces users interact with [9]. Some of the interactions with the interface are used to evaluate users' actions and draw conclusions about their obtained knowledge or information. The main setting for the story takes place at Azores deep sea. In the story the Azores' government has to make a decision about where to invest in order to enrich the local economy. On one hand, there has been some pressure from technological companies to invest in deep-sea mining, in order to use the mined minerals in building computers and smartphones. On the other hand, local communities are worried about the possible consequences of such activities on the Azores deep sea and its ecosystem, which itself contributes to economic growth providing an attractive area for tourism and fishing activities. The user's mission is to give their opinion about whether the government should approve deep-sea mining or stay away from it. They should embark on a submarine mission and evaluate mining possibilities. An outside view of the submarine can be seen in Figure 2. The setting and the issues users have to deal with, the knowledge, the experience and it´s design, are of major importance and have a direct impact on the evaluation methods used.

a. Look-at Evaluation

The look-at evaluation consists of determining if the user looked long enough at any specific objects that are valuable to the AS, using the user's gaze direction.

In order for the AS to be able to scan the environment for points of interest (POI), a component was created in order to detect this. This component can be attached to the user's virtual camera, so as to mimic the player's vision. This

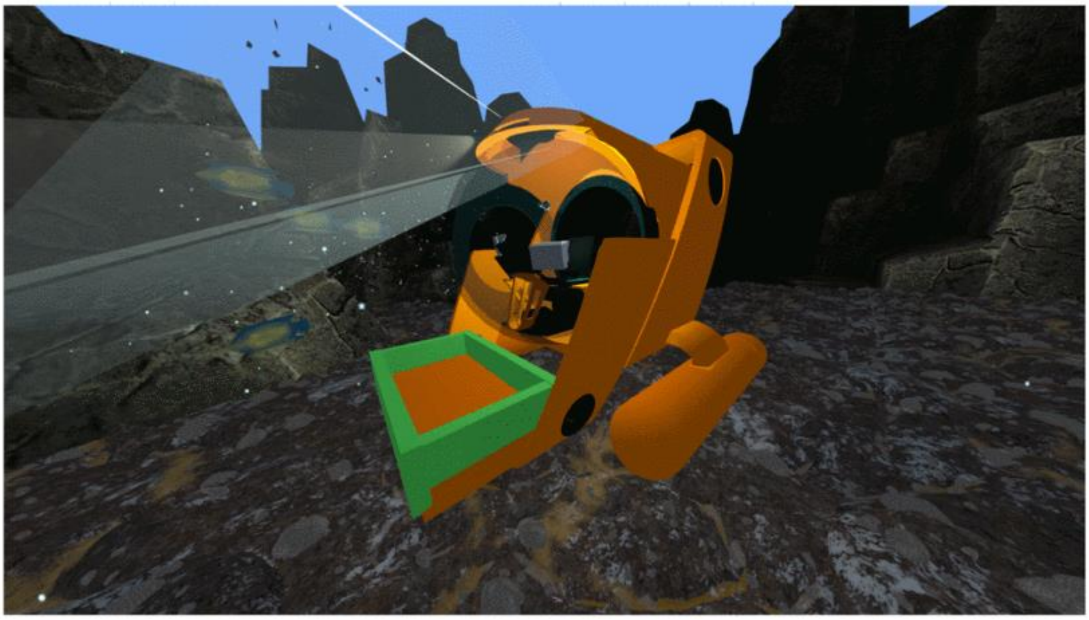

Figure 2: Submarine in Azorean sea.

component can, right from the start of the experience, be constantly shooting a raycast into the scene to look for interesting POI that are important to the AS. But only using a simple raycast proved to be problematic, as this would generate a lot of detection problems.

For example, the player could be using its peripheral vision in order to look at a specific POI. Using a simple raycast, the component would not be able to detect if the player was indeed looking at the POI, since the raycast would not intersect the POI in any way, because it is only shot directly at the center of the screen (based on the users' gaze direction), missing the POI (see Fig. 3). This problem can be minimized using a sphere cast. By using an appropriate sphere radius, it is possible to cast a sphere into the environment that will cover a larger percentage of the user's field of view, allowing the system to more easily detect where the player is looking, even when they are using their peripheral vision (see Fig. 4). The radius does not need to be big, as current generation HMDs only allow field of views with angles up to 110º, and since HMD's lens allow relatively narrow focus points, users would not exactly be using the edge of their peripheral vision since that part of the environment would be too blurred for them to truly notice or understand what was presented there without actually rotating their head towards that point.

The radius value that is used throughout the whole experience is 10 centimeters. This value was selected based on preliminary tests since the results regarding the object that the sphere cast was detecting versus what users were actually looking at were favorable with this value. It is worth pointing out that

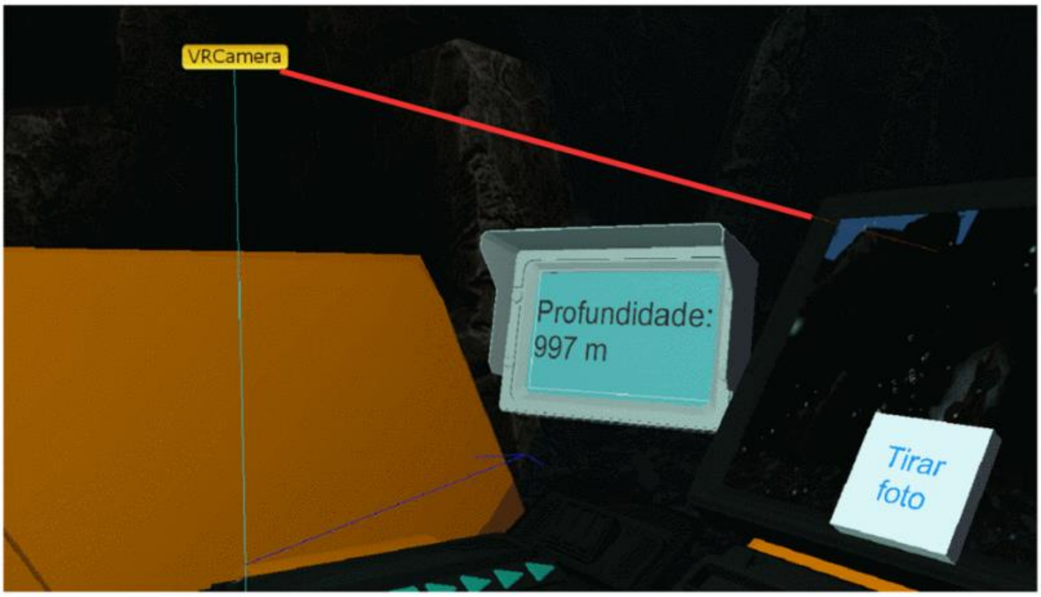

Figure 3: Using a simple raycast (red line), the POI is not detected, since it is not at the center of users' gaze, even if they are using their peripheral vision.

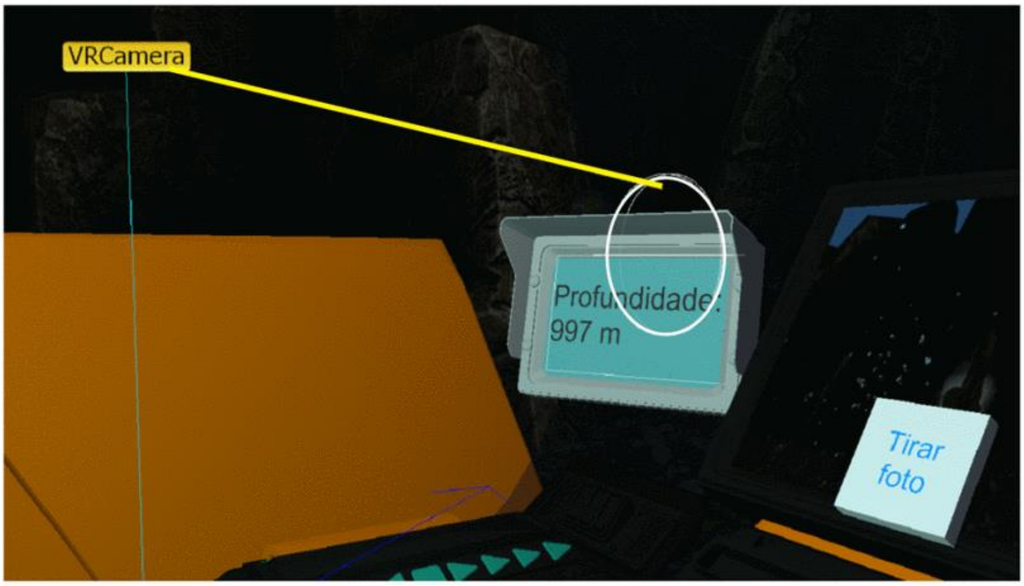

Figure 4: Using a sphere cast (yellow line, ending with a white sphere), the POI is detected, since it casts a sphere with a large enough radius to detect it.

this value may need tweaking when applying this evaluation technique to other VR experiences. Other games may need to adapt this value based on the scale of their own virtual world, as bigger scale also means that the sphere cast radius could be bigger, since big objects would automatically occupy a bigger portion of the screen, not requiring users to look directly at the center of the object.

In order for an object to be considered for evaluation as a look-at POI in the eyes of the AS, that object should be marked as such, and its acknowledge time specified. This is required because different objects may require different look-at times to be acknowledged by the system. Basically, each POI needs to have its own acknowledge time. This is very important, as this is the required time that a user must look at an object in order for the object to be considered acknowledged by the user, meaning that the user has paid sufficient attention to it that they will most likely understand what the object is or represents. In other words, users should look at the object for a specific amount of time in order for the object to be considered acknowledged by them, as different objects require different levels of attention, since they have different complexities. If the user is asked to read something in a virtual piece of paper in order to understand a specific problem, the acknowledge time of that piece of paper may be its reading time, allowing the user to read it all. For a computer screen that only indicates, for example, the current depth in meters, a simple glance at the screen of about 1 second may be enough, and when that POI is acknowledged, that information is saved by the AS in the form of a table, with 1 of the columns stating if the screen was acknowledged (see Look-at in Table I). Only when the user has looked at the object for its own specific amount of time is the object acknowledged.

If users start looking at an object but they look away from it without going over the acknowledge time, the time starts from zero the next time they look at it. This prevents non- intentional focusing, as users could just be looking around and checking the environment, with the possibility of the sphere cast intersecting a specific POI, accumulating time that was not actually used to focus the object, but in just generally exploring and looking around.

It is worth noting that a look-at evaluation could possibly benefit from the use of eye tracking technologies such as the Tobii Eye Tracker. Eye tracking technologies direct near- infrared light to the user's eyes, creating reflections that are tracked by an infrared camera. After some calculations, it is possible to detect where the user is looking, even if they are using their own peripheral vision to look at certain objects. Instead of trying to understand and iteratively adjust the best possible value for the sphere cast radius (as to simulate the player's attention zone), eye tracking could greatly improve the efficiency of such methods.

b. Interact Evaluation

The interact evaluation consists of determining if the user interacted with specific objects that are valuable to the AS and learned something from their interaction. If a certain information is only provided through a certain interaction, that is, in order for users to have access to a specific information they are required to interact with a certain interface, then, if they interact with that interface, they learn the information locked under it.

For instance, in this experience, users can ask for advice regarding the decision problem they are facing (explained at the beginning of the section). Such advice is only provided if they press the corresponding virtual button that triggers the dialog audio that provides that advice.

Table 2: Different evaluation examples.

<table>
<tr><td rowspan="2">Look-at</td><td rowspan="2">Deepness association</td><td colspan="2">Noticed Depth Screen</td></tr>
<tr><td colspan="2">Yes/No</td></tr>
<tr><td rowspan="2">Interact</td><td rowspan="2">Mining Exploration</td><td colspan="2">Advice Heard</td></tr>
<tr><td colspan="2">In Favor / Against</td></tr>
<tr><td rowspan="2">Time</td><td rowspan="2">Mining Exploration</td><td>Decision</td><td>Decision Time</td></tr>
<tr><td>Favor / Against</td><td>seconds</td></tr>
</table>

At the start of the experience, they were taught how to interact and press virtual buttons, so that they know how to trigger them. If such advice is only available to users if they press the corresponding advice button, and if the AS wants to evaluate if they learned some of the points stated in the advice, they must verify if users actually interacted with the advice button. If the dialog audio is simple and short, then users would have learned that information, and the corresponding table is generated, stating which advice they heard (see Interact in Table I.

Another example is when the submarine starts descending and the sunlight starts to fade away, eventually getting completely dark, so the AS wants to analyze if users understand if they know they need to press the light switch virtual button in order to light up the scene (see Fig. 5). This moment starts when it gets dark enough to justify turning on the lights. If the user takes more than 3 seconds to turn it on, a dialog hint plays informing the player that it is getting too dark, and if 7 more seconds pass without the user pressing the light switch, the lights get turned on automatically. Since this moment's particular objective is to understand if users know that they need to turn on the lights in dark places, the AS only considers the interaction with the button to turn on the lights important after it gets dark, since previous or future interactions with the button do not count towards verifying if the player actually understands they have to press the button. This introduces situational context to the evaluation, in which a certain evaluation may only happen in a given context and only at a specific moment during the experience in order to make sense. This way the system needs to have the ability to evaluate at specific times only, depending on the experience's design. If the user interacts with the light switch within the time frame of this moment, the AS will create the corresponding evaluation stating that they indeed turned. If they did that before or after the hint was provided, stating they understood that light changes based on depth. If not, the moment's evaluation reflects their failure.

c. Time Evaluation

The time evaluation consists of counting the amount of time a user took to accomplish a specific task.

It is possible to easily record the starting time of a specific task, and when the user finishes that task by means of gameplay, the starting time is subtracted from the finish time, offering an accurate time duration of the embraced task.

Every moment or event from the game can be timed for evaluation. This value can be used to understand if users had doubts regarding what to do or what to decide. If users are faced with a specific decision and are struggling to effectively decide, this might give insights that the user was carefully considering all the nuances of the task at hand, with the objective to make the best decision possible. If users took a surprisingly short amount of time to decide, it might be possible to conclude the users did not consider everything there was to measure or that they simply were certain regarding a particular choice. This evaluation gives some insights into their decision making.

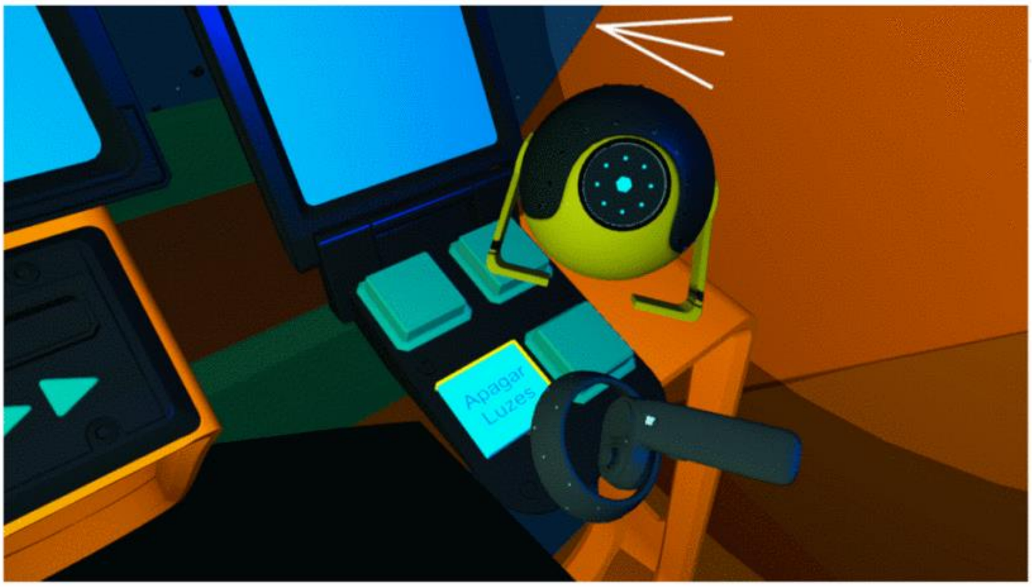

Figure 5: Analysis System evaluates if users pressed the light switch button.

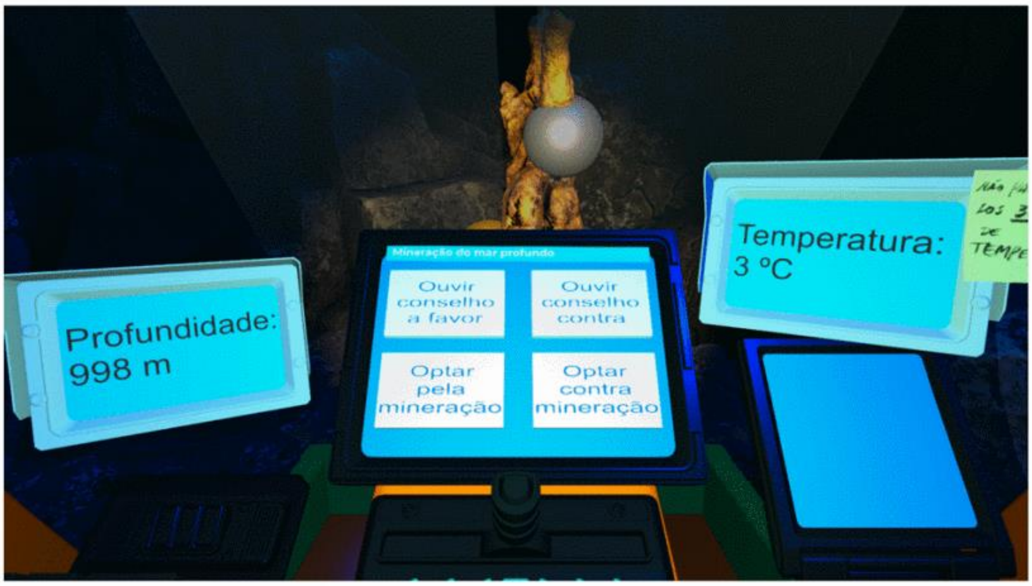

Figure 6: Users must press one of the decision button to make their decision. The Analysis System records the time they take.

One particular example is when users need to actually state their opinion regarding whether the government should approve deep-sea mining or stay away from it, by pressing the corresponding decision button (see Fig. 6). From the moment the decision is possible, time starts counting, and based on that time, it is possible to see if users struggled to decide or were very firm in their decision. Table I references this moment in the Time cell, where" seconds" represents a possible time value.

5. Evaluation

35 participants attended the user studies. 71% of users were male and 26% were female, while 1 user preferred to not state their gender. Participants' age has an average of 26.83, with a median of 23, ranging from 16 to 53. In terms of virtual reality experience, 91% of users had at least one previous opportunity to try VR, 57% were intermediate or above users, and 9% never tried VR before.

a. Protocol

Users play through the developed VR experience from start to finish. They face all the challenges and decisions while the AS is constantly tracking users' behaviour. There are a total of 5 evaluation moments. The first one evaluates if users know the temperature the submarine should not exceed, information that is displayed on a post-it, above the temperature screen as seen in Fig. 6. The second moment evaluates if players can visually describe 2 ecosystems that are displayed as images on a computer screen. The third moment evaluates if players acknowledge some of the information regarding two distinct ecosystems, displayed as bullet points on brochures available inside the virtual submersible. The fourth moment evaluates if players know how deep one of the ecosystems is located, by looking at the current depth screen when accomplishing the proposed tasks at that same ecosystem. The fifth and final moment evaluates if players know some of the reasons to be in favor or against deep-sea mining, by detecting if certain virtual buttons are pressed, playing an audio track with the corresponding advice dialog.

When users finish the experience, a set of questions are orally asked to the participants by an assistant, and depending on their answer, those questions are marked as correct, incorrect, or left blank (indicating that users did not know or did not notice the aspect of the question in the VR experience). The AS evaluated users regarding their obtained knowledge, providing conclusions as to what users learned and did not learn. The questions asked to participants were regarding the same evaluated knowledge, so as to match the answers provided by them with the evaluation from the AS. For instance, the AS evaluated the user with regards to the depth they were in (explained in section IV-A), generating Table I first section, which stated if participants looked at the screen that displayed their depth. One of the questions asked to participants was how deep they were, and if they answered correctly, in order to get a positive evaluation out of the AS, the AS also had to conclude that the user did indeed look at the screen.

b. Results

Table II displays the respective moment, aligned with the AS and user accordance and discordance percentage, so, for instance, when looking at "Maximum Temperature Detection", 85% of times the AS correctly concluded that the user knows or did not know the maximum temperature value (AS stated they know and they answered correctly, or the AS stated they did not know and the user answered incorrectly or did not answer at all), failing 15% of times (AS stating they know and they answered incorrectly, or the AS stating they did not know and they answered correctly). Each of the 5 moments have their own accordance and discordance percentage, displaying the success rate of the AS in each one.

Taking a look at Table III, it is possible to see the total amount of times the AS and the user were in accordance or discordance, pertaining the results of all the moments merged together. Table IV displays the results from a precision and recall test, including its accuracy, followed by the calculation of the F1 score.

c. Analysis

The AS had very high accuracy on some of the moments, and the majority of them were correctly evaluated, except the" Deepness Association" moment, which had an accordance rate of 40%.

Starting with the" Maximum Temperature Detection" moment, which had a accordance rate of 85% and discordance of 15% according to Table II, it is possible to see that this moment was the second highest rated. This high success rate in this specific moment may suggest that the moment itself was overall well designed, and that no major interference from other interactions took place. This also supports, at the first sight, the usage of look-at evaluations.

Moving to the" Image Recognition" moment, Table II shows that this moment had a 60% accordance rate. Although this moment still has a positive accordance rate, the drop in accordance is probably based on the less than ideal acknowledge time. The images on the computer screen had an acknowledge time of 3.2 seconds, which was probably not the best value, since this made the AS predict more times than not that the player should indeed know how to visually describe those images, since they acknowledged the computer screen. For some users, 3.2 seconds were enough, but some required more time in order to absorb the information displayed on the images in order be able to visually describe them. This suggests that the acknowledge time is a very important factor in the look-at evaluation, and a lot of consideration should be put into figuring out the best time for a specific moment.

Table 2: Accordance and discordance in each moment.

	Accordance	Discordance
Maximum Temperature Detection	85%	15%
Image Recognition	60%	40%
Brochure Recognition	73%	27%
Deepness Association	40%	60%
Advice Rephrasing	98%	2%

Table 3: Accordance and discordance between the AS and user.

	User knows	User does not know
AS says user knows	**121** (True Positive)	**48** (False Positive)
AS says user does not know	**11** (False Negative)	**41** (True Negative)

Table 4: Precision, recall, accuracy and F1 score calculation.

Metric	Score
Precision	0.72
Recall	0.92
Accuracy	0.73
F1	0.80

The next moment," Brochure Recognition", had an accordance rate of 73%. Since users had to verbally answer with at least one bullet point on the brochure that they could remember, and since those bullet points were brief and short, the acknowledge time for each brochure was 3 seconds. There are 2 factors that may contribute to the fact that this moment does not have an accordance rate similar to the last moment (98%): acknowledge time and object positioning. The acknowledge time design problem was addressed in the above moment analysis, but this moment may also suffer a new design problem, which is its own positioning. Both brochures are placed near the center of the submarine's frontal view, one slightly to the left and the other to the right, leaving some space between them so that players can see where they are going when moving the submarine (see Fig. 7 for a visually description of the problem). When this happens, the sphere cast that exists in order to detect POIs may detect one of the brochures, since users can have their head slightly rotated to one side as they move the submarine with the brochures still in display, starting counting towards the acknowledge time. When that time is surpassed, the AS receives the evaluation that the user did indeed look at the brochure for at least the intended amount of time, even if that was not their intention." Deepness Association" moment is the moment with the lowest accordance rate, and by watching the participants' recorded footage, the the strongest hypothesis is that this moment may suffer from asset design issue, also described above. When players wanted to drive the submarine using the

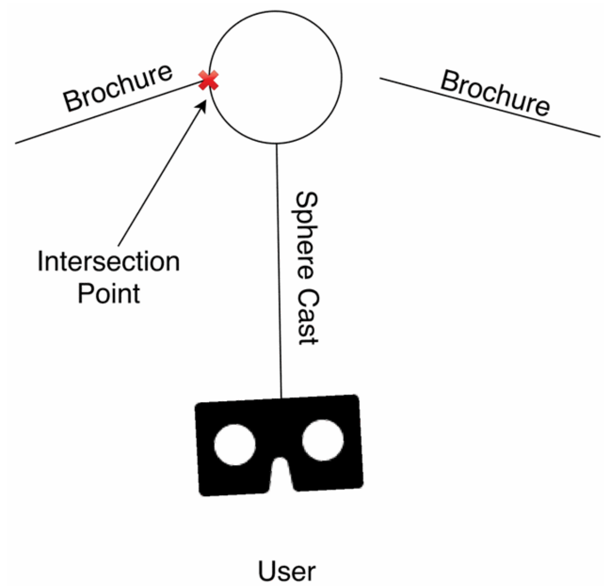

Figure 7: Brochure being detected by the sphere cast while users are slightly rotated when moving the submarine.

thrusters control, the depth screen was too close to the movement thruster (interface that allows the player to move the submarine), so when users looked to the thruster in order to grab it, the sphere cast radius attached to the player's camera was big enough to detect the depth screen, indicating to the AS that players looked at it for the required amount of time. Memory problems may have also occurred. Some users were visibly frustrated when trying to answer the question, as they stated they saw the value on the depth screen, but could not remember it, contributing to the decay of accordance.

The last evaluation moment," Advice Rephrasing", had the highest accordance rate.

The advice users heard was brief and very concise, in order to make it easy to understand. Since this moment used an interact evaluation, as opposed to a look-at one, it was easier for the AS to detect when an advice button was pressed, which would result in the AS concluding that the user should know the reasons explained when the button was pressed, and since this moment did not suffer from any apparent design problem, its success rate is very high.

In order to better understand the efficiency of the AS as a whole, its precision and recall were calculated, based on the information in Table III, with results displayed in Table IV. The calculated value for the recall was 0.92 (between 0 and 1), meaning that the system can find and correctly classify almost all the relevant information the user knows at the end of the experience, providing a good recall result. For precision, 0.72 was the calculated value, meaning that 72% of the results that the system states as relevant are actually relevant which, in this case, is when the AS states that the user learned and they actually did, and although less than the recall value, this value still offers a satisfying result. The system's accuracy was also calculated (0.73), although not as relevant, since this metric can sometimes be deceiving. F1 score was also calculated, giving a value of 0.80, suggesting that the AS is precise and robust, offering a good balance between precision and recall. These results suggest that this AS and the implemented evaluation techniques, as part of the many components that constitute this VR experience as a museum application, can be used with relative success to determine if users effectively learned what the application is teaching to the user.

6. Conclusions

When creating experiences with emphasis on learning, intrusive methods are still used in order to evaluate if users actually learned. When these experiences are used in the context of a museum, validating the user's knowledge acquired during the experience, has proven troublesome, since most users are not interested in answering further questions This work offers solutions to solve this issue, by proposing an Analysis System with evaluation techniques that is able to provide valuable insights about users obtained knowledge. User studies were performed with the objective to evaluate the quality and efficiency of the AS. These tests, which were performed by 35 users, validated the feasibility of the AS, which was able to accurately evaluate what was the user's knowledge when the experience ended most of the time.

Some parts of the systems were found that can be improved upon. Since one of the moments only had 40% of success due to the depth screen positioning, that screen should be placed in a different area or at least moved away from the movement thruster. As previously mentioned, this reinforces the need to design the experience in tandem with the Analysis System. This system may also be improved by using 2 acknowledge times as opposed to 1, as it was first planned. This is, of course, subject to further study.

With the implementation of this AS we hope that the base for user evaluation methods regarding scientific communication was established and can be further improved. These evaluation methods deserve continuous study and development due to their high importance. By designing and implementing new methods, the AS would improve on its robustness and flexibility, offering more evaluation variety. Applying eye tracking technologies to this system would be interesting, since it provides a more accurate way to process the user's gaze direction, hopefully removing some of the design restrictions mentioned during the analysis.

7. Acknowledgements

This work is financed by FCT (Fundação para a Ciência e a Tecnologia), by national funds through the UT AUSTIN Portugal Program within project UTAP-EXPL/CD/0106/2017.

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Communications in International Meetings with Abstracts Publication

Communicating Cutting-edge Science through VRE: Contributions from the I SEA Project

C. Morais, J. C. Paiva, L. Moreira, T. Aguiar, A. Teixeira

7th European Marine Science Educators Association Conference
Expolab, Lagoa, São Miguel, Azores, Portugal, 16-30 September 2019.

Abstract

The Atlantic International Research (AIR) Centre underlines the need for developing new communication strategies to bridge society with cutting-edge research and for educating stakeholders to generate awareness, understanding, engagement and critical support. The I SEA project focuses on the Azorean deep-sea, emphasizing some of the scientific areas of the AIR Center (deep ocean science and marine ecosystems valorization). It aims to develop a non-obtrusive, valid and replicable method to evaluate audience attitudes about science communication initiatives through an immersive virtual reality environment (VRE). The prototype will be hosted by Azores Science Centers, namely the Expolab and the Fábrica da Baleia - Azorean Sea Observatory (OMA). This communication reflects on the process of selecting the ecosystems and the trade-off model between development and sustainability underlying the VRE narrative. The choice of ecosystems (water column, hydrothermal vents, and coral gardens) was based on an iterative process of reviewing recent literature, consulting stakeholders and experts, and promoting discussion within the multidisciplinary team. Corals are expected to be familiar, attractive and perceived as fragile. Hydrothermal vents hold a unique richness in scientific content (e.g., chemosynthesis). Navigation through the water column offers a chance to observe biodiversity, including bioluminescent species. The narrative of the VRE asks visitors to solve socio-scientific dilemmas, without offering shortcuts for perfect outcomes. Instead, it confronts visitors with mixed results on the ecosystems, society or both, triggering the need for further making sense of the relation between science and society. Results from the fieldwork in the science centers will be discussed.

Non-invasive and Replicable Method for Evaluating Science Communication Activities: Contributions from I SEA Project

C. Morais, J. C. Paiva, L. Moreira, T. Aguiar, A. Teixeira

VII Congreso de Comunicación Social de la Ciencia
Burgos, Spain, 9-11 October 2019.

Abstract

The recurrent evaluation methods and procedures of science communication can be intrusive, privacy-menacing and conflicting with visitor's agendas. The project ISEA aims to develop a non-invasive, valid and replicable method for evaluating science communication activities in informal settings, e.g. science centers. It addresses the following issues: audience's attitudes, awareness, understanding and engagement about deep sea ecosystems; influences of a non-obtrusive evaluation method on visitor's acceptance, engagement and narrative creation; and similarity between data collected via this digital method and through conventional means. A transformational play framework will be adopted. Through an immersive virtual reality experience (VRE), visitors will take the role of the protagonist using their knowledge about deep sea ecosystems to solve complex prevailing dilemmas, while making sense of the consequentiality of their decisions to the ecosystems. Through the VRE, measures of visitor's awareness, understanding and engagement will be collected, as visitors make a virtual journey either into deep-sea coral or hydrothermal vents ecosystems. They need to explore the ecosystem and make sense of the information at their disposal in order to take important decisions about the relevance and sustainability of the ecosystems. As they travel back to the surface, they will be asked about the reasons behind their decisions. At the end of the VRE, they will receive a *deep-sea-gram*, i.e., a summary of their journey with a scientific key to help them to better read and signify the experience. Data obtained through conventional techniques will be compared with the data obtained in the VRE in order to test their concurrent validity. The goals emphasize the need for rethinking the way we evaluate science communication in informal settings by integrating evaluation in the process of communicating, so that it becomes relevant for the visitors. This exploratory project might serve as a prototype for other complex science phenomena.

Communications in International Meetings

I SEA - Virtual Reality to Evaluate Audience Attitudes about Science Communication

A. Coelho, C. Morais, L. Atkinson, A. Jacinto, R. Nóbrega, M. Varzim, J. C. Paiva, L. Moreira, T. Aguiar, A. Teixeira, J. Vieira, D. Coelho

UT Austin Portugal Program's 2019 Annual Conference
University of Minho, Braga, Portugal, 20 September 2019.

Abstract

Evaluation has moved up the agenda in Science Communication. However, some procedures, while available, may be too obtrusive to use recursively in science centers and/or conflict with science center visitors' agendas. Our idea is to develop a non-obtrusive, valid and replicable method to evaluate audience attitudes about science communication projects through an immersive virtual reality environment that can improve exhibitions while educating and empowering citizens. The immersive virtual reality environment will have two modalities: for one person (individual condition) and for a group of individuals (collective condition), that will be supported by a transformational play framework and multilinear storytelling. In this communication, we will report on the development of the individual condition. The environment consists of a capsule with head-mounted displays and headphones to provide an immersive experience that will take visitors into extreme deep-sea conditions, in particular, hydrothermal vents, scaffolded according to three levels – a) awareness, b) understanding and c) engagement – regarding science/technology processes and contents. Visitors will face several dilemmas, take intentional actions, based on the legitimate science content at their disposal, that will impact the context of the immersive environment. In the end, visitors receive a "deep-sea-gram", which is a summary of their path through the game. More than delivering stories, the "deep-sea-gram" is expected to push visitors to create and share their own stories about their experience and to signify their relationship with the scientific endeavor. The narrative of the game was developed and adjusted based on the iterations and multidisciplinary contributions of team members. Furthermore, the team asked for the feedback from external experts on the deep-sea content, tested the usability of the immersive environment prototype, conducted two field studies on the science centers that will host the exhibition, and promoted focus groups and interviews with non-experts. To develop a comparative framework, we will run several experiments to validate the method via within- and between-subjects plans. For testing the concurrent validity of the virtual, non-obtrusive method, we are currently developing a self-report questionnaire. This project not only contributes to greater audience awareness, understanding and engagement with deep-seas ecosystems but also provides conceptual innovations and empirical support to the integration of virtual reality as a means of communicating and evaluating science communication in non-formal spaces of education, such as science centers.

Reshuffling Virtual Reality and Science Communication: Synergies based on Transformational Play

L. Senra, C. Morais, L. Moreira

9th International Congress on Technology, Science and Society
Madrid, Spain, 3-4 October 2019.

Abstract

The present research was carried out in the context of the multidisciplinary project I SEA, which is focused on cutting edge scientific content about deep sea ecosystems, aiming to establish a new, replicable non-obtrusive method for the evaluation of science communication in scenarios such as science centers and museums, using virtual reality and the transformative play framework. As we were trying to develop a coherent and consistent with the transformative play framework narrative plot for the virtual scenario, the goal of this communication is to reassemble the plethora of agencies at work in the project. Based on the actor-network theory, we actively collaborated with one of the three sub-teams of the project (composed by physical-natural and social sciences researchers) over more than six months, taking field notes, analyzing and producing documents, meeting and interviewing with researchers, practitioners and public. The team was a sort of oligopticon, offering a limited (considering that the project has contributions from engineering and design), but deep perspective over the unfolding of the project. In the process, we understood how the affordances of the technology and theory, the views, expertise and availability of researchers, practitioners and public, and the time window of the project were impacting the work and uncovering unexpected perspectives. For example, because virtual reality is not familiar for most people and has technical limitations regarding displaying written messages, narrative options changed and the agency of the medium as well as the psychological identification with the character were reshuffled into the transformative play framework. The project unfolded not so much in spite of the limitations but because of the limitations we found. This case study is significant because it reassembles the agencies at work in the project, offering a in-depth view of their contribution for the implementation of a research and development, multidisciplinary project.

Discovering Social Representations of Deep Sea, Virtual Reality and Science Communication: Contributions from the Project I SEA

C. Morais, J. C. Paiva, L. Moreira, A. Teixeira, T. Aguiar

9th International Congress on Technology, Science and Society
Madrid, Spain, 3-4 October 2019.

Abstract

This research was carried out in the context of the project I SEA, focused on the development of a non-obtrusive method for evaluating science communication initiatives. It was intended to explore the social representations about the main concepts of the project: *deep sea* (message content), *virtual reality* (medium used) and *science communication* (field of the study). Through a snowball sampling strategy, we recruited 294 adult participants (87 males and 205 females) to answer an online questionnaire that included association questions about the stimuli related to the project main concepts. Participants were also asked to rank their answers according to their perceived importance. Prototypical and similitude analyses were conducted with the software IRAMUTEQ (version 0.7 alpha 2). Preliminary results suggest that *deep sea* is represented as a *dark, blue, cold, deep* and *immense unknown* region, populated with *fishes, sharks, corals* and *submarines*, inspiring *fear, tranquility* and *curiosity*. *Pollution* is referred by few participants. *Virtual reality* is objectified in specific equipment's such as *headsets* and anchored to *computers* and *games*, which appear associated with *immersion* and *interactivity*. Notwithstanding the associated *risk*, it appears to be a promising symbol for the *technology of the future*. Other drawbacks appear in the form of *illusion, alienation, falsity* and *addiction*, provoking a tension between promises and perils. *Science communication* evoked very diversified ideas, suggesting that the social representation is poorly structured. For the participants, it is presently an *important, relevant* and *essential* activity, consisting of *sharing, communicating scientific knowledge*, though *research papers*, *conferences* and *media*. The audience and its role are not very visible in the representation. Results are significant as they allow us to understand that the topics are paradoxically next to and far away from the audience, feeding the reflection about how to communicate and to evaluate cutting-edge knowledge in non-formal spaces.

Connecting Science Communication with its' Evaluation: Representations and Practices Ranging from Lay Public to Science Centers

C. Morais, L. Moreira, A. Teixeira, T. Aguiar

Public Communication of Science and Technology Conference 2020+1 [1]

Aberdeen, Scotland, 25-27 May 2021.

Abstract

We report a study on the social representations of science communication among the audience and in science centers to understand the meanings around the field of science communication and the relations between representations and practices in science centers.

A sample of 294 adult participants answered an online word association questionnaire. Prototypical and similitude analyses were conducted with *IRAMUTEQ*. Also, 10 participants from two Portuguese science centers (including stakeholders, staff and visitors) were interviewed about their views and practices on science communication and its evaluation. Data was analyzed with *NVivo*.

Results suggest that the public has a poorly structured social representation of science communication. Consisting of diversified and weakly tied ideas, science communication is represented as an important, necessary activity of sharing knowledge, via papers or conferences almost without references to the public and their role in science communication. Similarly, in science centers, science communication is mostly done by researchers, based on communicating factual information, in simple language to enhance the public's literacy. Science communication evaluation is restrained to obtaining informal feedback without systematic procedures. The science center's representations and practices suggest the prevalence of deficit and contextual models, given the emphasis on factual, even if contextualized, scientific content. Representations of science communication in science center's resonate with the public's poorly structured ideas.

The analysis corroborates the need to think of ways to promote audience's engagement and evaluation practices in science centers. The solution proposed by the I SEA Project, which focuses on deep-sea ecosystems, consists of moving evaluation into the center of the process of communication through a non-invasive procedure, i.e., virtual reality. Hopefully, the integration of communication and evaluation in a unique process, making it relevant both for institutions and visitors, will help to promote the adoption of more dialogical models and consolidate the value of science communication within the public.

[1] This abstract was already accepted for publication, although this event was postponed to May 2021.

Communications in National Meetings with Abstracts Publication

Avaliação e Comunicação de Ciência: Contribuições do Projeto I SEA

C. Morais, J. C. Paiva, L. Moreira, A. Teixeira, T. Aguiar

XVIII National Meeting of Science Education | III International Seminar of Science Education

Faculdade de Ciências da Universidade do Porto, Porto, Portugal, 5-7 September 2019.

Abstract

Os procedimentos de avaliação usados em centros e museus de ciência são muitas vezes invasivos e incompatíveis com a agenda dos visitantes. Alinhado com o *Atlantic International Research Center*, o projeto ISEA - *Immersive virtual reality environments to evaluate audience attitudes about science communication projects* – assume o tema dos mares profundos e pretende integrar a avaliação no processo de comunicação de ciência, desenvolvendo um método não invasivo e replicável para avaliar as atitudes do público em relação a iniciativas de comunicação de ciência, através de um ambiente de realidade virtual imersivo com base no jogo transformativo (Barab, Gresalfi, & Ingram-Goble, 2010).

Nesta comunicação, pretendemos descrever o processo de identificação, seleção, operacionalização e validação tanto do conteúdo científico a abordar como dos procedimentos de avaliação a implementar.

A análise exploratória da literatura científica sobre o mar profundo e a consulta de especialistas nacionais e internacionais permitiu identificar quatro ecossistemas relevantes: coluna de água, jardins de corais, agregações de esponjas e fontes hidrotermais. As informações recolhidas foram sistematicamente discutidas em reuniões semanais da equipa, gerando-se critérios orientadores do processo de construção do cenário imersivo e das medidas de avaliação. Com base na pertinência do conhecimento científico e nas características dos ecossistemas que poderiam contribuir para comunicar o tema ao público leigo (critérios axiológicos e estéticos), assistidos por constrangimentos de tempo e de meios, decidiu-se abordar, numa primeira fase, exclusivamente a coluna de água e as fontes hidrotermais. A operacionalização destes ecossistemas tem sido validada por especialistas e por utilizadores.

A experiência centra-se numa expedição virtual à coluna de água e ao campo hidrotermal *Lucky Strike* nos Açores (Langmuir et al., 1997), na qual os visitantes, a bordo de um submersível, assumem o papel de protagonistas e podem resolver desafios dilemáticos sobre a sustentabilidade destes ecossistemas, recorrendo, para tal, aos seus conhecimentos sobre mar profundo. Como consequência das suas decisões, os visitantes observam a transformação dos contextos, promovendo-se uma transformação do próprio visitante (Barab et al, 2010). No decorrer da experiência recolhem-se medidas de consciencialização, compreensão e envolvimento do visitante com a

experiência (Burns, O'Connor, & Stocklmayer, 2003). Durante a viagem regresso à superfície, o visitante participa numa entrevista virtual, podendo justificar as suas decisões e criar uma narrativa à volta da experiência vivida. O desenvolvimento e validação destas medidas encontra-se em curso. A reflexão em equipa levou ao questionamento dos modelos ecológicos prevalecentes na atualidade, equacionando-se a construção de uma escala de atitudes face aos ecossistemas do mar profundo que operacionalize uma nova visão ambiental, assente no equilíbrio entre sustentabilidade ambiental e desenvolvimento social. Assim, através da entrevista e do questionário, pretende-se estabelecer a validade concorrente do novo método não invasivo de avaliação. Este projeto contribui para a discussão sobre o lugar da avaliação na comunicação de ciência em espaços não formais, admitindo que a inclusão de estratégias avaliativas nas próprias atividades adquire valor para a construção de uma experiência significante para o visitante e para as instituições.

Keywords: comunicação de ciência, avaliação da comunicação de ciência, realidade virtual, mar profundo, jogo transformativo.

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O Módulo I SEA, Ao Encontro dos Centros de Ciência Viva

C. Morais, J. C. Paiva, L. Moreira, A. Teixeira, T. Aguiar

XVIII National Meeting of Science Education | III International Seminar of Science Education
Faculdade de Ciências da Universidade do Porto, Porto, Portugal, 5-7 September 2019.

Abstract

No âmbito do projeto ISEA, desenvolveu-se um módulo de realidade virtual (RV) imersiva que associa comunicação e avaliação da comunicação de ciência acerca dos ecossistemas do mar profundo dos Açores. O módulo será integrado em dois Centros Ciência Viva (CCV) – o Planetário do Porto, direcionado à Astronomia, e o Expolab, nos Açores, dedicado às Ciências Naturais e Tecnologia. Pretende-se caracterizar os dois CCV e compreender de que forma a sua missão, visão acerca do mar profundo, experiência com realidade virtual e condições de acolhimento moldarão a integração do módulo. Os dados foram recolhidos através de entrevistas semiestruturadas e observação do participante, com recolha audiovisual complementada por notas de campo. Foram atendidas as seguintes dimensões: caracterização do CCV, público-alvo, expectativas e representações sobre o módulo ISEA, condições humanas e tecnológicas, experiência com realidade virtual, conceções e experiência de comunicação e avaliação da comunicação de ciência, e experiência com o tema do mar profundo. Foram entrevistados 10 participantes, incluindo visitantes, responsáveis e colaboradores dos CCV. Os dados foram analisados através do programa *NVivo*. Os resultados preliminares demonstram que, apesar da temática do mar profundo não ser abordada em nenhum dos CCV, os intervenientes procuraram legitimar o acolhimento do módulo. No Planetário, a legitimação fez-se por via da isomorfia de natureza científica, estabelecendo-se um paralelo entre a exploração espacial e a exploração do mar profundo, ambos territórios hostis e remotos. Os visitantes referem que o módulo contribuirá para potenciar a interatividade e variedade de experiências disponíveis. A imersividade das sessões na cúpula permite ancorar a experiência de realidade virtual do módulo ISEA. Já no Expolab, a integração do módulo foi equacionada recorrendo a argumentos de cariz afetivo e institucional. Se a localização geográfica (Açores) confere legitimidade para abordar o tema, exige igualmente que se evite a redundância relativamente a outros espaços de ciência do arquipélago. Os depoimentos dos responsáveis, corroborados pela análise da programação e recursos disponíveis, sugerem que no CCV o multimédia assume um papel relevante na comunicação de ciência. Tratando-se de um CCV tecnologicamente enriquecido, as atividades desenvolvidas e implementadas, incluindo RV, contribuem para ancorar o módulo ISEA. As entrevistas aos responsáveis e colaboradores apontam para

a prevalência dos modelos de comunicação de ciência de défice e de contextualização (Lewenstein, 2003). Contudo, existem pontuais ações de diálogo com o público, configurando-se como passos a caminho de modelos dialógicos. Não apresentam práticas sistemáticas de avaliação da comunicação, embora reconheçam a importância para os visitantes e para a instituição, limitando-se à auscultação da satisfação do visitante. Justifica-se uma discussão sobre os processos de legitimação e de representação do módulo ISEA em espaços não-formais de comunicação de ciência. Se, por um lado, os meios e conteúdos da comunicação de ciência encontram várias formas de legitimação, os objetivos de integração da avaliação no processo de comunicação de ciência carecem de pontos de ancoragem. Importa, por isso, refletir sobre a estratégia para integrar as duas dimensões do módulo ISEA - comunicação e avaliação da comunicação – por forma a promover-se a sua relevância para instituições e visitantes.

Keywords: comunicação de ciência, avaliação da comunicação de ciência, realidade virtual, mar profundo, centros de ciência viva.

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Science Communication and Evaluation through Immersive Virtual Reality: Contributions from I SEA Project

C. Morais, J. C. Paiva, L. Moreira, A. Teixeira, T. Aguiar

CIQUP II Workshop Meeting

Faculdade de Ciências da Universidade do Porto, Porto, Portugal, 22 February 2020.

Abstract

Because every scientific endeavor is entangled with social and cultural threads, as one can observe in the public discussion about climate changes, it is critical to understand how the general audience is making sense of the messages conveyed in the media and in everyday talks about science. In this communication, we report on how general audience is making sense of the deep-sea - a cutting-edge scientific topic often described as the last frontier [1]. In the context of the exploratory FCT funded I SEA project - focused on communicating and evaluating science communication in informal spaces through non-obtrusive methods - we aimed at mapping people's attitudes, perceptions and social representations on deep-sea. Also, we wanted to understand the relationship between socio-demographic and psycho-sociological variables with the semantic field of the social representations [2]. Through a snowball sampling, we recruited 315 participants - 217 (68.9%) females and 95 (30.2%) males (3 missing cases) to fill a questionnaire with three sections: (1) free association questions about deep-sea, among other stimuli; (2) multiple-choice questions on reported significance and perceived risk about deep-sea (3) an attitudinal scale on the deep-sea. Data were analyzed with *IBM SPSS Statistics* (version 26) for factorial and reliability analysis, *Iramuteq* (version 0.7) for prototypical and similitudes analysis and *DtmVic* (version 6.0) for correspondence analysis. The internal structure of the attitudinal scale revealed three dimensions: economic exploration (M = 2.39, SD = 0.80); preservation (M = 4.34, SD = 0.50), and scientific exploration (M = 3.80, SD = 0.68). Pollution (M = 4.83, SD = 0.50), garbage (M = 4.83, SD = 0.50) and climate change (M = 4.52, SD = 0.80) were perceived as great threats to the deep-sea. The social representation of the deep-sea seems to be on its first stages of construction given that it is not possible to properly differentiate which words are the best candidates to the core of the representation. As for the semantic field of deep-sea, it was structured on two axes - one opposing known to unknown, the other opposing emotions to reason. The conjugation of these factors resulted in four dimensions: the image of the surface of the sea; leisure; fear; and finally, scientific and technological developments. The positioning of the illustrative variables in these quadrants showed they are relevant for understanding the way people are making sense of deep-sea. For example, while on the surface quadrant participants were characterized by an educational

level up to secondary and by considering fishing a moderate threat to the deep-sea, on the fear quadrant we find participants who hold a graduation degree, are highly engaged with science communication activities and do not consider research a threat to the deep-sea. Results are significant to better understand how the general audience is dealing with new scientific topics, about which they might have to make important political decisions. It suffices to remind how deep-sea ecosystems, like hydrothermal vents, are unique, fragile and rich. In hydrothermal vents scientific, economic and preservations goals meet. The I SEA project results urge for the development of new ecological paradigms [3], where sustainability needs to be rethought in order to cope with the entangled nature of socio-scientific challenges.

Acknowledgements

This work is financed by FCT (Fundação para a Ciência e a Tecnologia), by national funds through the UT AUSTIN Portugal Program within project UTAP-EXPL/CD/0106/2017.

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Comunicação de Ciência e Mar Profundo: Perceções, Conhecimentos e Atitudes do Público Português

C. Morais, J. C. Paiva, L. Moreira, T. Aguiar, A. Teixeira

8th SciComPt Congress 2020
Online edition, 7 May-18 June 2020.

Abstract

Com mais de 90% do território submerso, Portugal poderá ser considerado sinónimo de mar. A sua localização tem impulsionado medidas políticas estratégicas como a "Missão para a Extensão da Plataforma Continental" ou a designação de áreas marinhas protegidas. Entre muitas iniciativas, o mar profundo integra, ainda, o tema da agenda do *Atlantic International Research Center*. Contudo, apesar dos avanços científicos e tecnológicos, o mar profundo permanece, em grande medida, desconhecido e inexplorado, sendo parca a informação que chega ao público em geral.

É nesta conjuntura que surge o projeto de investigação I SEA, que pretende comunicar e avaliar a comunicação de ciência acerca dos ecossistemas do mar profundo, por meio de uma experiência de realidade virtual. Utilizando dois protótipos de realidade virtual disponíveis em dois Centros de Ciência Viva - o Expolab (Açores) e o Planetário (Porto) -, os visitantes são convidados a integrar uma expedição ao campo hidrotermal *Lucky Strike*, localizado nos Açores. Este desenvolvimento, entre outros aspetos, decorreu a par com a investigação sobre o que pensam os portugueses acerca do mar profundo. Para tal, desenvolveu-se um questionário composto por: uma escala atitudinal sobre o mar profundo, questões de associação livre e questões acerca da importância e conhecimentos sobre o mar profundo. A elaboração deste instrumento teve como base a literatura científica sobre o mar profundo, tendo-se adicionando aspetos específicos habitualmente não abordados, como por exemplo o papel da investigação científica. Nesta comunicação, centramo-nos essencialmente nos serviços e recursos do mar profundo que os inquiridos consideram como mais revelantes, assim como aquelas que são percecionadas como as principais ameaças a estes ecossistemas.

O estudo realizado contou com 315 respondentes, 217 do sexo feminino e 95 do sexo masculino, sendo na sua maioria de nacionalidade portuguesa, entre 35 e 39 anos e com um nível de formação superior. No caso da importância do mar profundo, os resultados indicam que, em geral, os inquiridos consideraram o mar profundo relevante para uma diversidade de serviços e de recursos, como a energia, a tecnologia ou a alimentação, sendo unânime o reconhecimento do seu papel para áreas como a educação e ciência e o clima e meteorologia. A importância do mar profundo para áreas como o lazer, o turismo e o emprego não reuniu a mesma convergência de respostas. Em relação às ameaças ao mar

profundo, a maioria dos participantes considerou essencialmente a poluição, o lixo e as mudanças climáticas. Das hipóteses apresentadas, a investigação científica foi a menos apontada como uma ameaça, ainda assim, cerca de 17% dos participantes entenderam-na como uma potencial ameaça. Estes resultados são semelhantes à perceção do público europeu, quanto à relevância dos oceanos, ao destacar o clima e a meteorologia e subvalorizar o lazer, o turismo e o emprego, bem quanto à identificação das suas principais ameaças.

Futuramente, iremos analisar de que forma as perceções do público quanto à importância e ameaças ao mar profundo se articulam com as suas representações e atitudes face ao mar profundo. Estes resultados serão complementados pelos dados decorrentes da implementação da experiência de realidade virtual (a decorrer), sendo expectável que o I SEA potencie a discussão sobre a avaliação da comunicação da temática do mar profundo, assim como a promoção da consciencialização, compreensão e envolvimento dos visitantes de espaços de educação não-formal.

Keywords: educação não formal, museus e centros de ciência.

Master Thesis

Knowledge and Interaction Analysis System for VR Museum Applications

José Vieira

Master thesis, Master in Informatics and Computing Engineering

Faculdade de Engenharia da Universidade do Porto, July 2019.

Abstract

Understanding specific academic content in a short period of time can be difficult. Scientists and the general scientific community are always trying to inform the population, but such knowledge may be difficult to grasp. One of the reasons is that the population may not understand how to apply that knowledge to a specific context and the formats in which that knowledge is available may not fully engage the user, like in museum exhibitions. Just memorizing knowledge is not the best way to be aware of it. Museums may even have boring and inaccurate evaluation methods, like questionnaires, which may not provide accurate results regarding the visitor's obtained knowledge since they are usually not interested in being evaluated.

Video games, in combination with virtual reality, can provide efficient learning methods, methods that actually use knowledge in ways that the user must reason about and understand in order to actually apply it into solving a specific problem. The primary goal is not to memorize the given knowledge, but instead, understand it so that problems can be solved by actually applying it.

This dissertation's purpose is the conceptualization, implementation, and evaluation of a valid, replicable and non-intrusive Analysis System in a VR game experience for museums. This system's objective is to be aware of the user's actions while evaluating and classifying such actions regarding the knowledge obtained by the user throughout the experience, without them even being aware of the existence of such a system, providing an engaging and fun experience to the user.

A collection of evaluation types was created, each with a different approach when evaluating the user, so as to adapt to different gameplay circumstances. The system's evaluation is then exported at the end of the experience for easy reading, stating key points regarding the user's evaluation.

As part of the evaluation process of the Analysis System, user studies were conducted in order to assess the efficiency of the implemented solution. Users went through the VR game experience, faced certain challenges and made decisions while the Analysis System evaluated them. Participants also answered questionnaires regarding their obtained knowledge, and their answers were faced against the evaluation created by the Analysis System for each particular participant. Results indicate that carefully designed experiences can use the created evaluation techniques in order to evaluate the obtained knowledge from the user. Some considerations were also defined to help guide the game's design process when these techniques are applied.

Keywords: analysis system, interaction interfaces, virtual reality.

Citation

Vieira, J. (2019). *Knowledge and Interaction Analysis System for VR Museum Applications.* Integrated Master in Electrical and Computers Engineering, Faculty of Engineering of University of Porto.

https://repositorio-aberto.up.pt/handle/10216/122841

O Multimédia e a Realidade Virtual nas Práticas de Comunicação de Ciência em Espaços Não-Formais: Um Estudo das Representações Sociais

Ricardo Simões

Master thesis, Master in Multimedia

Faculdade de Engenharia da Universidade do Porto, July 2019.

Abstract

Science communication is a subject that has worried the scientific community due to the separation between the public and the science itself. To reverse this trend, non-formal science communication spaces have focused their efforts on bringing science closer to the public, particularly younger audiences, using tools such as multimedia. Virtual reality, a technology that allows multimedia communication and whose popularity has grown in recent years, is one of the tools adopted in some of these spaces, so it's relevant to evaluate how this integration has been made. This project intends to understand how virtual reality is represented by the directors of these spaces, while identifying the results of its integration and the role that this technology has in the involvement of the visitor. First, a documentary analysis was done on the websites and Facebook pages of the 21 Centros Ciência Viva, in order to identify the activities, scientific areas and multimedia devices of the center, and to obtain a general understanding of the relationship between the centers and the multimedia. Next, a questionnaire was sent to all the centers in order to confirm the observations made during the documentary analysis, as well as the relationships between them, and to identify centers where virtual reality activities have never taken place and where they have already taken place. Finally, directors of 6 Centros Ciência Viva were interviewed, while exploring topics such as the integration of multimedia in the science communication of the centers, with particular regard to virtual reality, and the role of the visitor in the activities of the center. These interviews were also used to identify how the previous topics are represented by the directors of the centers, a central issue in this dissertation. After an analysis of the collected data, it was verified that the multimedia is usually associated with the integration of the image with the sound, and that it plays an important role in a large number of activities, which are multimedia dependent. Despite the broad multimedia adoption, virtual reality, associated with "simulation" and "reality that does not exist", has not yet been adopted on a large scale, with limitations of both centers and virtual reality being the reason for that. These limitations are usually mentioned by centers that already had virtual reality activities, which means they have experienced these limitations firsthand. Nevertheless, the centers agree that virtual reality plays an important role in the attraction and involvement of visitors, not only because of the interesting contents, but also because it is a novelty for many. As for the visitors, they are given a central role in the activity of the centers, since the centers are built for them. Also, because of that, it is expected and advised by the centers that, whenever possible, the visitor plays an active role in the activities of the center and in the science communication. With this research it was possible to understand the relevance of multimedia and virtual reality in the science communication, particularly in non-formal spaces of communication of science, and the important role played by the visitors of these spaces.

Keywords: multimedia, virtual reality, science communication, non-formal education, social representations.

Citation

Simões, R. (2019). *O multimédia e a realidade virtual nas práticas de comunicação de ciência em espaços não-formais: Um estudo das representações sociais*. Master in Multimedia (Education), University of Porto.

https://repositorio-aberto.up.pt/bitstream/10216/121893/2/346396.pdf

Realidade Virtual e Comunicação de Ciência: Uma Abordagem Baseada no Jogo Transformativo

Luiza Senra Pereira

Master thesis, Master in Multimedia

Faculdade de Engenharia da Universidade do Porto, September 2019.

Abstract

Virtual Reality (VR) is considered the great promise of technological innovation and has been applied in several areas, the main one being entertainment. However, there is a potential use in the area of education, with a gap in its application in the context of science communication. This study aims to analyze how virtual reality, supported by an approach based on transformational play, can contribute to the communication of science. The research is based on the case study of the I Sea Project, an immersive virtual reality experience on deep sea ecosystems for the lay public. The methodology for this investigation consists on the monitoring, observation and analysis of the project, based on the ANT theoretical framework (Actor Network Theory). To this end, the instruments used were the recording and analysis of the meetings and documentation of the project, as well as semi-structured interviews to understand the relationships between VR technologies, transformational play and deep sea communication. Thus, this study has special relevance to the areas of multimedia and communication science, as it opens the way to a better understanding of the role of transformational play in the development of an experience in VR in the process of transmitting information of scientific content.

Citation

Pereira, L. (2019). *A Realidade Aumentada no contexto da comunicação da ciência*. Master in Multimedia (Education), University of Porto.

https://repositorio-aberto.up.pt/bitstream/10216/123267/4/361927.2.pdf

Workshops

Science Communication and Evaluation, the I SEA example

C. Morais[1], L. Moreira[2], T. Aguiar[1], A. Teixeira[1]

[1]Faculty of Sciences and [2]Faculdade de Engenharia da Universidade do Porto

I SEA Summer School | TED4SC – Technology, Engineering and Design for Science Communication

Faculdade de Ciências da Universidade do Porto, 17-19 June 2019.

Overview

This workshop will function as the opening session for the *I SEA Summer School | TED4SC – Technology, Engineering and Design for Science Communication*. A discussion of what science communication means, what aspects it involves and what models of applying it exist will make way to a debate on the current literature gap about how to evaluate science communication. Hence, we will introduce the I SEA Project and its main goals within the scope of deep-sea science communication and its' evaluation. The workshop will include a group activity focused on the reading and interpretation of news about the deep sea and a reflection on the main dimensions and environmental attitudes which arise to surface to the participants while reading them.

Figure 2: The *Science Communication and Evaluation, the I SEA example* workshop during the group activity, opening the I SEA Summer School at 17 of June of 2019.

Digital Composition on the Unreliable Canvas: Visual Effects and Animation Techniques in VR

Ben Bays
The University of Texas at Austin

I SEA Summer School | TED4SC – Technology, Engineering and Design for Science Communication
Faculdade de Ciências da Universidade do Porto, 17-19 June 2019.

Overview

Using techniques drawn from the disciplines of visual effects, motion graphics and animation, this workshop will cover how to enhance and manipulate 360 video to clarify and emphasize content. Participants will gain the understanding of how to control the elements and principles of composition in this emergent media.

Figures 2-3: The *Digital Composition on the Unreliable Canvas: Visual Effects and Animation Techniques in VR* workshop during the I SEA Summer School, at 17 of June of 2019.

Design and Engineering Going Hand in Hand with Science Communication

J. Vieira[1], R. Nóbrega[1], A. Jacinto[2], J. Barboza[1]

[1] Faculdade de Engenharia da Universidade do Porto and [2] ESAD – Escola Superior de Artes e Design

I SEA Summer School | TED4SC – Technology, Engineering and Design for Science Communication

Faculdade de Ciências da Universidade do Porto, 17-19 June 2019.

Overview

This workshop will include a presentation of the technological development behind the I SEA virtual experience, as well as a discussion of the perks of designing for science communication purposes. As a plus, participants will have the opportunity to try out the I SEA virtual reality experience. The second part of this workshop will include an introduction to 360 video production and hands-on activities, including recording and exhibition of participants' videos at the Planetarium dome.

Figures 4-10: The *Design and Engineering Going Hand in Hand with Science Communication* workshop, during the I SEA Summer School at 18 of June of 2019.

Roundtables

Science Communication: The Virtual Reality Challenges

I SEA Summer School | TED4SC – Technology, Engineering and Design for Science Communication
Faculdade de Ciências da Universidade do Porto, 19 June 2019.

Moderator Alexandre Jacinto *ESAD – Escola Superior de Artes e Design*

Invited Speakers

Beatriz Sousa Santos *Department of Electronics, Telecommunications and Informatics, University of Aveiro*
Beatriz Sousa Santos is Associate Professor in the Department of Electronics, Telecommunications and Informatics (DETI/UA), University of Aveiro, Portugal, and a researcher at the Institute of Electronics an Informatics Engineering of Aveiro (IEETA). Currently her main research interests are Data and Information Visualization and Virtual and Augmented Reality.

Susana Fernando *Department of Electronics, Telecommunications and Informatics, University of Aveiro*
Susana lives in Porto and reconciles the practice of Graphic Design with teaching since 1998. She has her own studio with occasional collaborations with other designers and photographers. Worked on projects for Transport and Communications Museum, Porto Polytechnic Institute, FEUP Museum, INESC Porto, ISPUP, FCUP, among others. She is a teacher at ESAD, School of Arts and Design - Matosinhos. As part of her Ph.D. in Art Education at the Faculty of Fine Arts of Porto, she is currently exploring the role of images as enhancers and the participation of the designer in the process of scientific research.

Science Communication: From Development to Evaluation

I SEA Summer School | TED4SC – Technology, Engineering and Design for Science Communication
Faculdade de Ciências da Universidade do Porto, 19 June 2019.

Moderator Carla Morais *Faculdade de Ciências da Universidade do Porto*

Invited Speakers

Maria João Fonseca *Natural History and Science Museum of the University of Porto*

With a degree in Applied Animal Biology and Biology Teaching and a PhD in Teaching and Dissemination of Science, Maria João Fonseca is currently Director of Communication at the Museum of Natural History and Science at the University of Porto. She has extensive experience in the design, implementation and evaluation of educational activities in formal and non-formal learning environments, as well as in institutional communication. Among her interests are topics such as scientific culture, the intersection between art and science in promoting it, science education in informal environments, especially museums and science centers, active learning methodologies and assessment of the impact of educational experiences.

Emílo Remelhe *Faculty of Fine Arts of the University of Porto*

Emílio Remelhe (born in 1965) is guest assistant at FBAUP. Teaches Creative Writing and Illustration at ESAD - Matosinhos. Bachelor of Arts - Painting, Master in Practice and Theory of Drawing, PhD in Artistic Education by FBAUP. Develops activity in the field of plastic arts, illustration and literature. It is represented in the collections of ANACOM, the World Trade Center-Macao, the Orient Foundation, the Macao Cultural Center, the Art Center of S. João da Madeira, the Serpent Gallery, the Faculty of Fine Arts Museum of UP and the Amadeo de Souza Cardoso Museum. He develops writing for children, theater and advertising. Work of writing and illustration edited by Caminho, Campo das Letras, Civilização, Eterogémeas, Edições Gémeo, Deriva, Bags of Books, Abysmo, Books of the Orient, Porto Editora and in magazines such as Malasartes, DP Photographer, Margins and Confluences, Macao Magazine, Revista UP, Search, Pli. His pseudonym Eugénio Roda was nominated by the Portuguese Society of Authors for the

2010 Authors Prize in the category of literature for children. His collaborations as an author and trainer include entities such as the Rector's Office at the University of Porto, the Belém Cultural Center, Public and School Libraries, Le Transfo, Blaise Pascal University, University of Minho, University of Porto, Serralves Museum, RTP-Canal 2, Vila Flor Cultural Center, Association Cardan, Polytechnic Institute of Macau, Polytechnic Institute of Porto, Arts Laboratory, Casa da Música, Gil Vicente Academic Theater, Bolhão Theater, Maria Matos Theater.

Paulo Nuno Vicente *NOVA School of Social Sciences and Humanities*

Paulo Nuno Vicente is an Assistant Professor of digital media at Universidade NOVA de Lisboa (Portugal). He founded and coordinates iNOVA Media Lab, a digital creation laboratory developing research at the convergence of creative digital media and emerging technologies. The lab is anchored around six key thematic areas: immersive and interactive narrative, information visualization, digital methods and web platforms, science communication, digital journalism and the future of education.

iSea

A Science Communication R&D project